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Hydrologic modelling of the relaxation of operational constraints in the southern connected system:

Methods and results

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Summary

On 29 June 2012, the Murray–Darling Basin Ministerial Council requested that the Murray–Darling Basin Authority (MDBA) complete a 'relaxed-constraints' model scenario with a Basin-wide reduction in diversions of 3200 GL/y. The purpose of this scenario is to explore the flow regime changes and potential environmental benefits that would result if some major existing river operating constraints in the southern connected system were relaxed. This report documents the approach used and outcomes of that work.

Background

In November 2011 MDBA released the draft Basin Plan proposing an Environmentally Sustainable Level of Take (ESLT) of 10,873 GL/y—representing the recovery of 2,750 GL/y of water for the environment. The ESLT and water recovery amount were informed by a program of environmental flow assessments and modelling that commenced in 2009 and which was reviewed and refined through 2010 and 2011. In simplified terms the approach adopted by MDBA was to:

- develop Basin wide and subsidiary indicator site environmental objectives and targets. Examples of ecological targets include providing a flow regime to sustain flood dependent vegetation communities in a healthy condition and which supports the habitat and breeding requirements of waterbirds (refer the proposed Environmentally Sustainable Level of Take report, MDBA 2011c)
- determine environmental flow indicators to meet ecological targets for indicator sites. Flow indicators are expressed as a flow magnitude or volume, duration, timing and frequency as each of these components of the flow regime are important for achieving ecological targets. For example, overbank flows with a certain duration, frequency and timing are important for maintaining wetlands and river red gum communities. Site-specific flow indicators were developed drawing on scientific research, observations of outcomes from past flow events, and analysis of historical flow patterns (refer Basin Plan environmental water requirements reports, MDBA 2012a)
- model the capacity for selected water recovery options to achieve the frequency of flows associated with those flow indicators (refer Basin Plan modelling report, MDBA 2012b)
- use understanding of the links between flows and ecosystem responses to estimate the magnitude of improved ecological outcomes (this process is summarised in the proposed Environmentally Sustainable Level of Take report, MDBA 2011c).

In 2011, using this approach to inform the determination of the ESLT, the MDBA assessed the potential environmental outcomes associated with three ESLT options representing the recovery of 2400, 2800 and 3200 GL/y respectively. These three options were selected on the basis of past MDBA modelling, together with modelling undertaken by others (e.g. modelling undertaken to inform The Living Murray, Jones et al. 2002), and socio-economic assessments, as representing the range likely to achieve the requirements of the Water Act and management objectives for the Basin proposed by MDBA.

The modelling and associated assessments showed that 2400 GL/y was insufficient to achieve a number of key environmental objectives for the River Murray downstream of the Murrumbidgee junction (including the Coorong, Lower Lakes and Murray Mouth); while 3200 GL/y delivered few additional environmental benefits relative to the 2800 GL/y option.

One of the key insights gained through this work was the impact of river operating constraints on achieving certain environmental outcomes, particularly in the southern Basin. The modelling indicated 2,750 GL/y would be sufficient to achieve environmental objectives for in-stream processes, streamside vegetation, low-level wetlands, and low-level floodplain environments; but the benefits to higher level floodplains in the southern Basin were minimal. The 3,200 GL/y modelling option showed marginal improvements in some outcomes; but no significant improvement for mid- and high-level floodplain environments in the southern Basin. This was because river operating constraints were found to limit the ability to deliver sufficiently high flows to inundate mid- to high-elevation floodplains; thus outcomes such as watering vegetation communities like river red gum and black box woodland on these floodplains was unachievable, regardless of the SDL volume.

Within the boundaries of these constraints and the consideration of social and economic impacts, MDBA therefore proposed an SDL reflecting a 2,750 GL/y reduction in diversions.

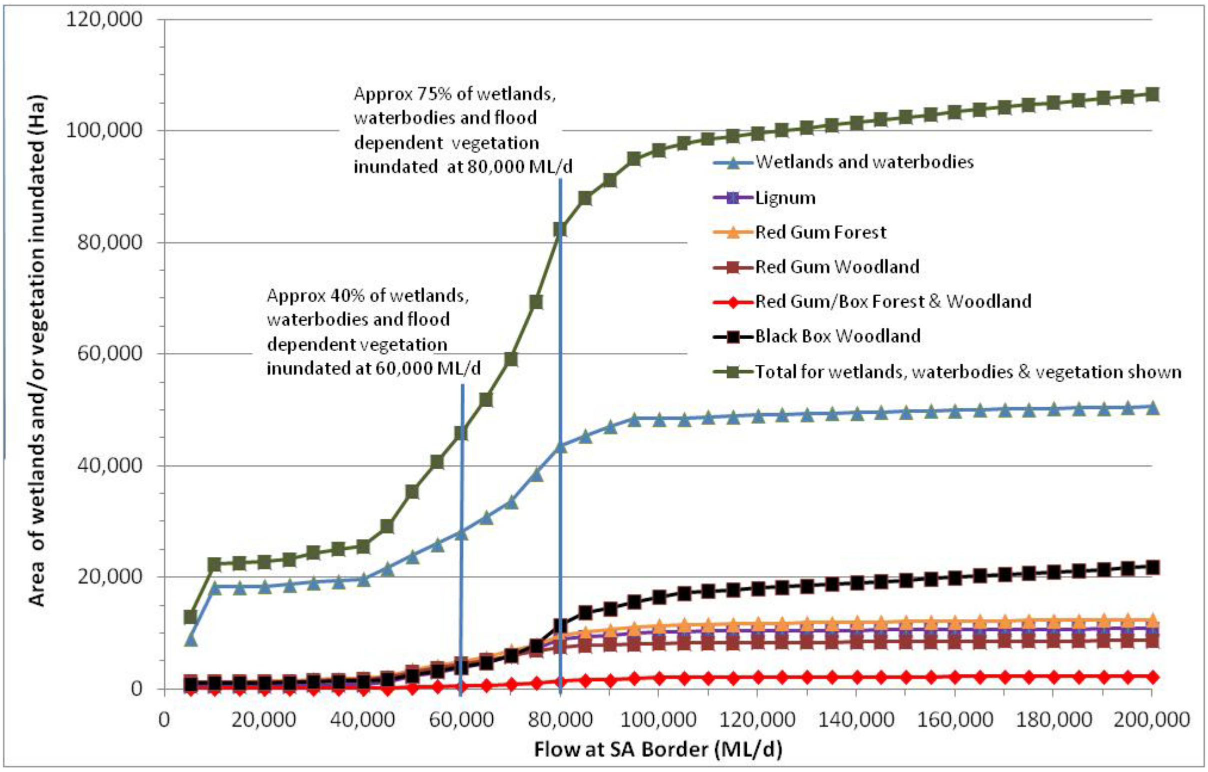
Potential benefits of overcoming constraints

River regulation and water use for consumptive purposes has significantly altered the flow regime of rivers across much of the Murray–Darling Basin. In lowland rivers such as the River Murray, the frequency at which floodplain and wetland habitats are inundated has significantly reduced; in many locations being now less than half what it was under pre-regulation conditions. Similarly, the length of time between flood events during dry times has grown substantially. In many locations it is now more than twice that experienced prior to regulation and diversion of river flow. This reduction in watering has had a significant impact on the health of those environments and across much of the Basin these habitats are transitioning from flood-dependant vegetation such as black box woodland to flood-tolerant communities such as samphire and chenopod shrublands.

Modelling undertaken to inform the draft Basin Plan showed it is possible to reinstate sustainable watering frequencies for in-stream processes, streamside vegetation, low-level wetlands, and low-level floodplain environments; but the frequencies required to sustain mid- to high-level floodplains in the southern Basin could not be achieved because of river operating constraints. The impact of constraints on the higher parts of the floodplain are particularly pronounced in the lower sections of the River Murray; where the cumulative effect of constraints, coupled with the cumulative effect of diversions throughout the Murray–Darling system are realised.

The potential benefits of overcoming river operating constraints are demonstrated in Figure E.1, which shows the relationship between flow rate and the extent to which wetlands and dominant floodplain vegetation communities are inundated for the River Murray between the Darling junction and Lock 1. Previous Basin Plan modelling (MDBA 2012b) indicated that under current river operating constraints it might be possible to reinstate a sustainable flow regime up to a flow rate of about 60,000 ML/d for the River Murray at the SA Border. Figure E.1 indicates this flow would inundate around 40% of the wetlands and dominant vegetation communities in that reach of the River Murray between the Darling junction and Lock 1.

Figure E.1: Relationship between inundation of wetlands and flood-dependent vegetation and flow in the River Murray between the Darling River junction and Lock 1.

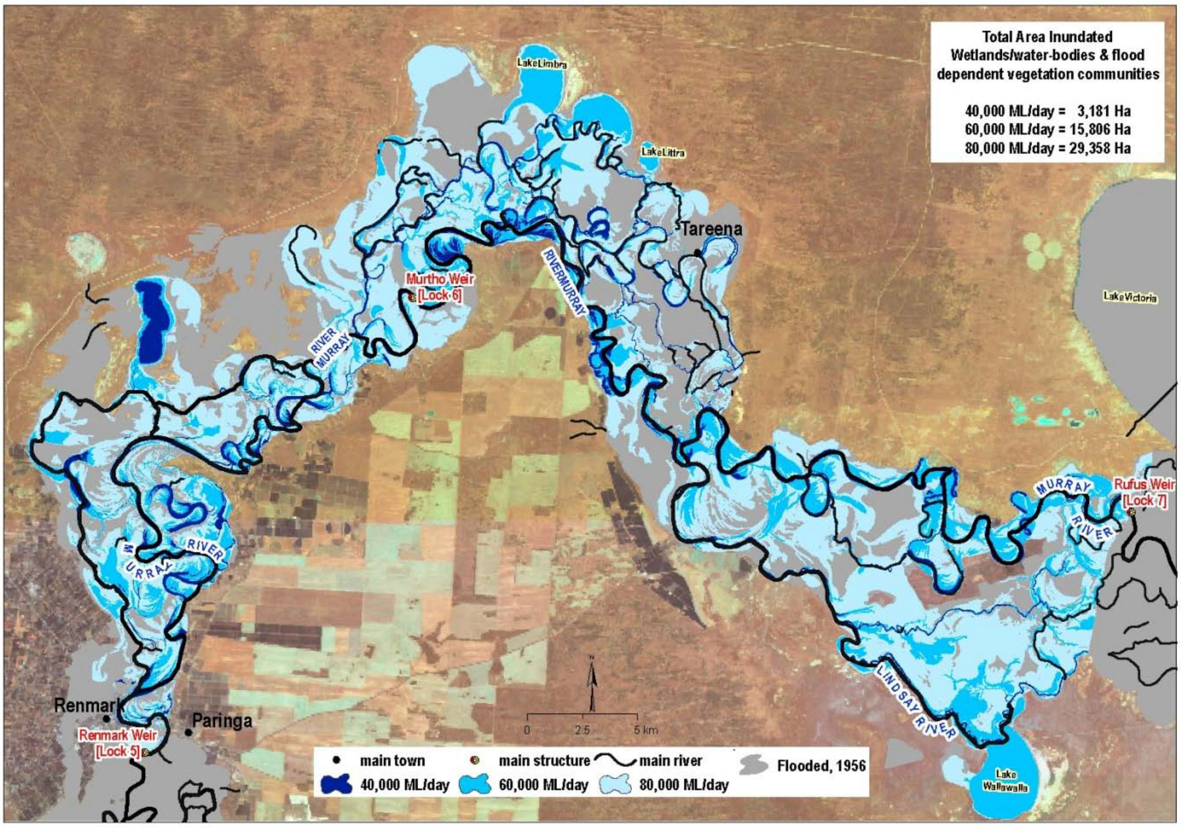


Note: The percentage of wetlands and vegetation communities inundated at 60,000 and 80,000 ML/d is expressed as a percentage of the area inundated at 200,000 ML/d. This does not represent the full extent of the River Murray floodplain (the 1956 flood event was over 300,000 ML/d); but areas above 200,000 ML/d are inundated very infrequently and are unlikely to support vegetation that requires frequent inundation.

Based on MDBA's preliminary assessment, it may be possible to overcome river operating constraints and increase the area of floodplain for which environmental water could be actively managed up to about 80,000 ML/d. There is a significant increase in the area of waterbodies and flood dependent vegetation that is inundated along the Lower River Murray downstream of the Darling River junction associated with an increase in flows from 60,000 ML/d to 80,000 ML/d (Figure E.1 and Figure E.2). As such it would be desirable to be able to target the active delivery of environmental water up to this level.

However, this would require a commitment and significant investment from both state and federal governments and would be subject to further assessments, cost/benefit analysis (including assessments of any third party impacts) and extensive community consultation. Overcoming constraints to this extent would mean that the area that can be watered increases significantly—to about 75% of the wetlands and dominant vegetation communities of the floodplain. For this reach of the River Murray alone this would equate to more than 30,000 ha of additional benefit; and a similar scale of additional area would be inundated further upstream and downstream of this reach. This outcome could be of critical importance to the long-term sustainability of vegetation communities that inhabit the higher elevation areas of floodplain in our lowland rivers (such as black box woodlands). Environmental outcomes for higher parts of the floodplain above 80,000 ML/d are dependent on large, unregulated flows as river operators cannot readily manage water delivery to these parts of the floodplain as it would involve a much greater degree of flooding risk.

Figure E.2: Map showing area of floodplain inundated between Locks 5 and 7 on the River Murray, with flow to South Australia of 40,000 to 80,000 ML/d.



Approach to the modelling task

To identify the extent to which overcoming river operating constraints can achieve higher flows and better environmental outcomes, the MDBA has completed two 'relaxed constraints' model scenarios representing Basin-wide water recovery of 2800 and 3200 GL/y respectively. These scenarios are referred to in this report as 'BP-2800-RC' and 'BP-3200-RC'. These new scenarios are an extension of the previous BP-2800 and BP-3200 scenarios that contributed to the determination of the proposed ESLT as described above (MDBA 2011c, 2012b). Accordingly, any identified possible improvements to the modelling methods were not applied to the relaxed constraints scenarios to ensure modelling consistency, required for robust assessment of the benefits of relaxing constraints.

The relaxed constraints scenarios encompass two significant modifications to the previous BP-2800 and BP-3200 scenarios:

- Eight of the key river operating constraints in the southern Basin were 'relaxed' in the modelling to increase the peak rate at which environmental flows can be delivered.
- An altered environmental watering strategy was adopted, necessitated by and taking advantage of the relaxation of constraints.

Table E.1 lists the eight river operating constraints relaxed in the model scenarios. Seven of these represent an increase in the allowable discharge to pass key river reaches in the southern Basin. The eighth represents the inclusion of a new regulator on the Darling Anabranch to accommodate efficient delivery of Menindee releases made to contribute to environmental flows to the Murray.

The Murray and Goulburn models were configured in a way that only allows the relaxing of these constraints during times of environmental water delivery—the flow constraints were maintained at their existing levels at all other times. Similarly, the regulator on the Darling Anabranch was closed only when there was a downstream environmental demand in the River Murray—to allow more water to pass down the Darling River to the Murray. At all other times the regulator remained open allowing flows to enter the Darling Anabranch (noting that explicit environmental demands for the Lower Darling are not included in the modelling).

Table E.1: Existing constraints applied in the models or demands for the proposed Basin Plan scenarios (MDBA, 2012b) and their increased values for the relaxed constraints scenarios.

Region	Location	Existing constraint (ML/d)	Relaxed constraint in model (ML/d)
Murray	Hume to Yarrawonga	25,000	40,000
	Downstream of Yarrawonga	22,000[1]	40,000
Lower Darling	Weir 32/Increase Menindee outlet capacity	9,300	18,000
	Darling Anabranch	Water flows into the anabranch at flows over 9,300 ML/d (no regulator)	Regulator added and closed above 9,300 ML/d when water is supplied from Menindee to meet environmental needs in the Murray
Murrumbidgee	Gundagai	30,000	50,000
	Balranald	9,000[2]	13,000
Goulburn	Seymour	12,000	15,000
	McCoy's Bridge	20,000[2]	40,000

Notes:

1. Constraint was already relaxed to 40,000 ML/d in previous Basin Plan modelling (MDBA, 2012b); however, the Hume to Yarrawonga constraint of 25,000 ML/d was in place meaning the 40,000 ML/d limit could not be effectively utilised.
2. Constraint is applied to tributary demands designed to contribute to achievement of downstream environmental water events in the River Murray.

The environmental watering strategies developed for the BP-2800 and BP-3200 scenarios were modified for the relaxed constraints scenarios. Through the modelling process it was found that the relaxation of constraints allowed a greater volume of water to be released from storage to deliver on existing environmental flow demands (those in the original BP-2800 and BP-3200 scenarios). Put another way: existing river operating constraints were limiting the delivery of demands in the previous model scenarios, and relaxing constraints allowed those demands to be more fully delivered. Without a change to the environmental watering strategy, this would have delivered additional volumes of environmental water exceeding the amount available to the environment in some years and negatively impacting on the reliability of supply to consumptive users.

Consequently, the selection of environmental watering events required adjustment, and this adjustment adopted an emphasis on reducing the water dedicated to low-flow events and adding it to high-flow events where possible. This changed strategy implies a greater emphasis on high-flow events to inundate a larger proportion of the floodplain at an increased frequency, consistent with a river management situation where there is greater ability to deliver high flows. This reallocation process was conducted largely without affecting the achievement of other flow targets as represented in the existing BP-2800 and BP-3200 scenarios; and baseflow and freshes demands remained unchanged from the previous model scenarios (except for the CLLMM/freshes demand which changed marginally).

Results of relaxing constraints with 2800 GL/y water recovery

Summary

Overall, the model results indicate that combining 2800 GL/y of recovered water with constraint relaxation would have a positive effect on the ability to deliver high-flow events; enabling greater areas of mid- to high-elevation parts of the River Murray floodplain to be inundated for longer periods and at a greater frequency. However, in order to detect changes using the flow indicators developed by MDBA to assess modelling scenarios, the improvements in flow have to meet specified flow rate and durations before environmental outcomes can be inferred. The BP-2800-RC modelling showed that while, in general, the duration and peak of existing events could be extended (providing environmental benefits), the events were not enhanced sufficiently to achieve additional flow indicator targets for mid- to high-level floodplains.

Floodplain outcomes

In the BP-2800-RC scenario the relative coarseness of the flow indicators generally means they are not able to detect smaller positive changes to the flow regime (see Table E.3). There are, however, more subtle changes in the flow regime and a more detailed analysis was undertaken to understand those changes. Box E.1 highlights the main outcomes of relaxing constraints with 2800 GL/y of water recovery.

Changes to the flow regime because of the relaxation of constraints for the Riverland-Chowilla Floodplain indicator site (measuring River Murray flows across the South Australian border) are discussed here as an example. An important flow threshold at this location is 60,000 ML/d, above which flows are sufficiently in excess of channel capacity to inundate substantial areas of flood-dependent vegetation such as river red gum woodland and lignum. Under baseline conditions (a representation of the water sharing arrangements as of June 2009 with no Basin Plan), the average number of days per year with flows in excess of this threshold is 19.5. In the BP-2800 scenario this increased to 25.4 days/y, an increase of 30%. With the relaxation of constraints in the BP-2800-RC scenario, this value increased to 26.9 days/y; an increase of 38% from baseline conditions.

Box E.1: Summary of environmental benefits from relaxing flow constraints with 2800 GL/y of water recovery.

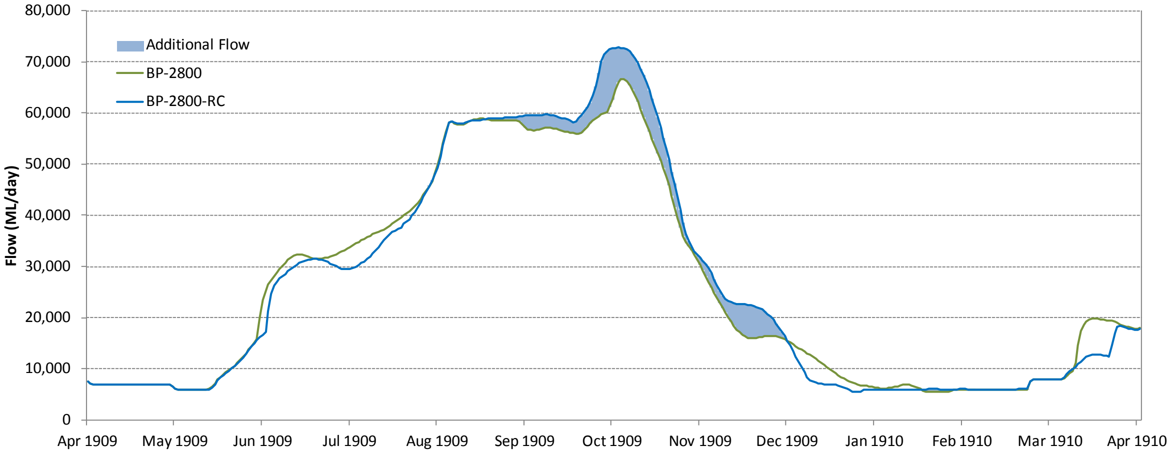
Environmental benefits of relaxing constraints — 2800 GL/y

- increased *flow peak and duration* for existing inundation events in the southern Basin
- overall, no *net* change in the number of environmental flow indicators achieved, but:
    - the achievement of an additional high-flow target in the Upper Murray (Barmah–Millewa Forest indicator: 35,000 ML/d for 30 days)[1]
- an increase in the average number of *high-flow days per year* in the Lower Murray.

Note: the near channel vegetation and low-level floodplain flow target was no longer achieved at Gunbower–Koondrook–Perricoota Forest (frequency of 20,000 ML/d for 60 days flow indicator reduced by 1%, no longer satisfying the target). The inability to achieve this flow indicator is an indirect consequence of changes to the environmental watering strategy and modelling limitations. In reality, the ability to deliver these events would be enhanced if constraints were relaxed and with efficient river operations it may be possible to achieve this flow indicator.

These benefits are further demonstrated in Figure E.3, which shows the modelled flow for a specific event in 1909. Under the original BP-2800 scenario, the flow (green line) largely meets the desired flow as described by the flow indicator (60,000 ML/d for 60 days). Assessed against the flow indicator, the result is much the same in the BP-2800-RC scenario (blue line). However, the peak flow increased from 66,600 ML/d to 72,800 ML/d, and the duration of the event above 60,000 ML/d doubled from 13 days to 26 days. The increase in peak flow by 6,000 ML/d would correspond to the inundation of an extra 8,000 ha of wetlands and flood-dependent vegetation communities between the Darling junction and Lock 1. Similar improvements to the flow regime were also observed at other sites and reaches along the River Murray.

Figure E.3: An example flow hydrograph of flow to South Australia showing benefits from relaxing river operating constraints. The flow indicator targeted by this flow event is 60,000 ML/d for 60 days for the Riverland–Chowilla floodplain.



Note: the hydrological modelling that underpins the Basin Plan uses 114 years of historical climatic data for the period 1895 to 2009, see MDBA (2012b).

The increased peak flow and the extended flood duration (BP-2800-RC scenario) would likely result in:

- improvements in the health and resilience of inundated flood-dependent vegetation
- refreshed floodplain groundwater systems
- flushing of salt from the landscape
- improvements in lateral connectivity and nutrient and carbon exchange between the floodplain and river which support fundamental ecosystem functions.

Obtaining expert advice on the expected environmental outcomes was outside the scope of the current project. Further work to identify the environmental benefits of flooding for periods shorter than the specified flow indicators may help to inform whether the outcomes and the additional flexibility to deliver environmental water would warrant the costs and time to address constraints.

Results of relaxing constraints and 3200 GL/y water recovery

Summary

The BP-3200-RC scenario indicates that the combination of constraint relaxation and an additional average of 400 GL/y of available environmental water:

- can substantially increase environmental benefits, with many more flow indicators being met for the River Murray (Table E.2)
- could provide the capacity to water mid- to high-level parts of the floodplain in the Lower Murray (with the potential to benefit large areas of natural wetlands and floodplains).

Table E.2: Achievement of 'actively managed'[1] river channel and floodplain environmental flow indicators achieved on the River Murray for the baseline and Basin Plan scenarios[2].

Scenario	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Number of flow Indicators achieved — River Murray	0/18 (0%)	11/18 (61%)	11/18 (61%)	13/18 (72%)	17/18 (94%)

Notes:

[1] 'Actively managed' refers to those flow indicators which are considered within the capacity for managed delivery under relaxed constraints conditions.

[2] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

[3] The scenarios discussed in this report are shaded in grey.

Floodplain outcomes

With additional water recovery (a further 400 GL/y for the environment) and a relaxation of constraints (to improve the ability to deliver environmental flows), there are likely to be substantial positive outcomes for the flood-dependent ecosystems along the River Murray. Unlike the BP-2800-RC scenario above, the flow regime changes are significant enough to substantially increase the number of environmental flow indicators achieved (Table E.3). These benefits are summarised in Box E.2.

Box E.2: Summary of environmental benefits from relaxing flow constraints with 3200 GL/y of water recovery.

Environmental benefits of relaxing constraints — 3200 GL/y

- *flow peak and duration* for inundation events in the southern Basin were further increased
- 17 of the 18 'active management' flow indicator targets in the River Murray were achieved
- several *high-flow targets at four River Murray hydrologic indicator sites* were achieved, indicating the potential for improved environmental outcomes for the mid- to high-level floodplain and colonial waterbird breeding:
    - 35,000 ML/d for 30 days at Barmah–Millewa Forest
    - 40,000 ML/d for 60 days at Gunbower–Koondrook–Perricoota Forest
    - 20,000 ML/d for 150 days at Gunbower–Koondrook–Perricoota Forest
    - 70,000 ML/d for 42 days at Hattah Lakes
    - 80,000 ML/d for 30 days at Riverland–Chowilla Floodplain
- limited improvement in achievement of Coorong, Lower Lakes and Murray Mouth flow and salinity indicators compared to the benefits of additional environmental water recovery alone as represented in the BP-3200 scenario.

The natural shape of the River Murray channel and its floodplain below the Darling junction provides an important flow threshold at 60,000 ML/d, above which flood waters breakout onto the wider floodplain and begin to inundate substantial areas. As the flow rises from 60,000 to 80,000 ML/d, the area of inundation grows—rapidly increasing the area of wetlands and flood-dependent vegetation inundated from approximately 45,000 ha to 80,000 ha.

On average, this area was inundated at least once every 3 years under without development conditions with the frequency of inundation reduced to about one in 10 years under baseline conditions (current conditions as at 2009). The frequency of these events increased to once every 8 years in the BP-2800 and BP-2800-RC scenarios. However the frequency improves significantly to once every 5.5 years in the BP-3200-RC scenario. This substantial improvement in the watering regime would provide significant improvement to the health of floodplain vegetation, such as river red gum and black box woodland and lignum shrublands. It would also provide enhanced outcomes for other species such as waterbirds, and improve ecosystem function outcomes associated with improved nutrient and carbon exchange, enhancing aquatic productivity.

The pattern and duration of dry spells are also important to the overall health and resilience of water dependent ecosystems. The constraints relaxed modelling indicates the potential for benefits in terms of reducing the maximum period between events (maximum dry spell) and the overall distribution of dry spell events. As an example of these benefits, Basin Plans scenarios are effective at reducing maximum dry periods to within known resilience periods for wetland communities at the Gunbower-Koondrook-Perricoota Forest hydrologic indicator site. The results are however variable depending on the specific modelling scenario, hydrologic indicator site and/or flow indicator which in part reflects that the primary modelling focus was the achievement of flow indicator target frequencies.

Table E.3: Proportion of years containing a successful environmental event for four hydrologic indicator sites on the River Murray.

Hydrologic Indicator Site	Flow indicator	Target: high to low uncertainty	Without develop-ment	Baseline	BP-2800*	BP-2800-RC*	BP-3200*	BP-3200-RC*
Barmah-Millewa Forest	12,500 ML/d for 70 days	70 - 80%	87%	50%	83%	82%	83%	82%
	16,000 ML/d for 98 days	40 - 50%	66%	30%	58%	52%	61%	55%
	25,000 ML/d for 42 days	40 - 50%	66%	30%	44%	46%	47%	46%
	35,000 ML/d for 30 days	33 - 40%	53%	24%	30%	33%	31%	35%
	50,000 ML/d for 21 days	25 - 30%	39%	18%	16%	14%	18%	16%
	60,000 ML/d for 14 days	25 - 30%	33%	14%	11%	11%	11%	10%
	15,000 ML/d for 150 days	30%	44%	11%	38%	39%	36%	39%
Gunbower–Koondrook–Perricoota Forest	16,000 ML/d for 90 days	70 - 80%	86%	31%	68%	67%	71%	71%
	20,000 ML/d for 60 days	60 - 70%	87%	34%	60%	59%	61%	61%
	30,000 ML/d for 60 days	33 - 50%	60%	25%	38%	36%	39%	38%
	40,000 ML/d for 60 days	25 - 33%	39%	11%	18%	20%	24%	25%
	20,000 ML/d for 150 days	30%	43%	7%	27%	25%	29%	32%
Hattah Lakes	40,000 ML/d for 60 days	40 - 50%	67%	30%	46%	45%	50%	46%
	50,000 ML/d for 60 days	30 - 40%	47%	19%	32%	32%	33%	35%
	70,000 ML/d for 42 days	20 - 33%	38%	11%	18%	17%	21%	20%
	85,000 ML/d for 30 days	20 - 30%	33%	10%	13%	13%	14%	15%
	120,000 ML/d for 14 days	14 - 20%	23%	8%	8%	8%	8%	8%
	150,000 ML/d for 7 days	10 - 13%	17%	5%	5%	5%	6%	6%
Riverland–Chowilla Floodplain	20,000 ML/d for 60 days	72 - 80%	89%	43%	72%	68%	75%	74%
	40,000 ML/d for 30 days	50 - 70%	80%	37%	61%	58%	61%	57%
	40,000 ML/d for 90 days	33 - 50%	58%	22%	36%	34%	39%	36%
	60,000 ML/d for 60 days	25 - 33%	41%	12%	25%	25%	27%	25%
	80,000 ML/d for 30 days	17 - 25%	34%	10%	14%	13%	14%	18%
	100,000 ML/d for 21 days	13 - 17%	19%	6%	5%	6%	7%	6%
	125,000 ML/d for 7 days	10 - 13%	17%	4%	4%	4%	4%	4%

🟩 Low uncertainty frequency or better
🟢 Low uncertainty to high uncertainty frequency range
🟨 Below high uncertainty frequency; improvement relative to baseline
⬜ No environmental demands specified in model -
Demands not included in previous MDBA modelling that informed ESLT. The majority of these are considered beyond capacity for managed delivery and therefore not part of 'actively managed' floodplain

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Coorong, Lower Lakes and Murray Mouth outcomes

Modelling indicated that relaxing constraints would provide relatively subtle changes to outcomes for the Coorong, Lower Lakes and Murray Mouth (CLLMM) (Table E.4). For the BP-2800 and BP-2800-RC scenarios the modelled outcomes are about the same, with some indicators slightly improving, and some indicators slightly worsening. This is consistent with the slightly different water delivery strategy in the relaxed constraints scenarios. A similar trend occurred with the two 3200 GL/y scenarios (BP-3200 vs BP-3200-RC); where there were some slight improvements and slight decreases against target values but the overall results were not significantly changed. The minor-scale changes to CLLMM indicators in the constraints relaxed scenarios was not unexpected given that achievement of these indicators is more reliant on volume rather than delivery of peak flows. As such, while there may be subtle environmental outcomes from relaxing constraints, the MDBA indicators are unlikely to be particularly sensitive compared to upstream sites which rely on high flows to inundate mid- to high-parts of the floodplain.

Consistent with the Basin Plan modelling scenarios in which constraints were maintained, there was a marked improvement in outcomes at the CLLMM from additional water recovery (i.e. comparing both 3200 GL/y recovery scenarios with the 2800 GL/y recovery scenarios) for the constraints relaxed scenarios. All modelled Basin Plan scenarios showed a significant improvement in CLLMM flow and salinity indicators relative to baseline conditions.

Table E.4: Flow and salinity indicator achievement for the Coorong, Lower Lakes and Murray Mouth.

Indicator	Target	Without develop -ment	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Average salinity (g/L) in Coorong southern lagoon over model period	less than 60 g/L	24	62	44	43	41	41
Maximum salinity (g/L) in Coorong southern lagoon over model period	less than 130 g/L	67	291	119	111	97	98
Max period (days) salinity in Coorong southern lagoon is greater than 130 g/L	0 days	0	323	0	0	0	0
Proportion of years salinity in Coorong southern lagoon < 100 g/L	greater than 95%	100%	82%	96%	99%	100%	100%
Average salinity (g/L) in Coorong northern lagoon over model period	less than 20 g/L	12	29	21	20	20	20
Maximum salinity (g/L) in Coorong northern lagoon over model period	less than 50 g/L	49	148	56	61	47	43
Max period (days) salinity in Coorong northern lagoon is greater than 50 g/L	0 days	0	604	75	114	0	0
Proportion of years 3 year rolling average barrage flow greater than 1,000 GL/y	100%	100%	91%	99%	99%	99%	99%
Proportion of years 3 year rolling average barrage flow greater than 2,000 GL/y	greater than 95%	100%	79%	98%	97%	99%	98%

Murrumbidgee and Goulburn River systems

As part of this modelling, key constraints were also relaxed in the main tributary systems (the Murrumbidgee and Goulburn systems) to improve environmental outcomes in these valleys, and to increase the flows directed towards downstream environments on the River Murray. The model results showed that all flow indicators for both constraints-relaxed scenarios were maintained or improved. Constraint relaxation allowed the achievement of a high-flow target frequency for the mid-Murrumbidgee River wetlands (44,000 ML/d for 3 days) in the BP-3200-RC scenario. In the Goulburn River, relaxing the constraint at McCoy's Bridge to 40,000 ML/d for downstream environmental demands in the River Murray resulted in greater frequency of flows between 20,000 and 40,000 ML/d in both the BP-2800-RC and BP-3200-RC scenarios.

Consistent with the altered environmental water delivery strategy to redistribute volume towards the higher component of the flow regime, the relaxation of constraints allowed enhanced flows from these tributaries, which contributed to achievement of high-flow environmental events in the River Murray.

Feasibility of addressing constraints

Undertaking detailed assessments and analysis to identify whether any of the constraints tested in this study could actually be relaxed was not within the scope of this report. To date, the MDBA has only undertaken preliminary assessments of flow delivery constraints such as those identified in the report on the proposed Environmentally Sustainable Level of Take (MDBA 2011c, Tables 5.1 and 5.2).

The revised Basin Plan includes the requirement for a Constraints Management Strategy to undertake a comprehensive and rigorous assessment of river operating constraints in consultation with the Commonwealth Government, Basin state jurisdictions and key stakeholders (including landholders). This work will help to confirm the extent of the 'actively managed' floodplain and it is likely to take several years to implement priority actions identified within the initial Constraints Management Strategy, which is to be completed 12 months after the commencement of the Basin Plan. The types of actions that would be investigated within that framework include:

- obtaining flood easements
- upgrading access infrastructure (roads, bridges)
- enhancing flood mitigation works (e.g. levees)
- increasing outlet capacity for some dams.

It is important to note that even if the Constraints Management Strategy confirms the feasibility of overcoming constraints and that the benefits outweigh the costs; delivery of environmental flows to the 'actively managed' floodplain are still generally not expected to exceed currently identified minor flood levels. Any third party impacts that arise from these events would need to be addressed through mechanisms such as easements.

Conclusions

Relaxing some key constraints with a 2800 GL/y reduction in diversions improved modelled environmental outcomes, but not on a scale sufficient to be detected by the present Basin Plan flow indicators.

The ability to release water at a higher rate is the main reason higher peaks were achieved for high-flow events under the BP-2800-RC model scenario. Higher flow peaks and extended durations through relaxing constraints are likely to have ecological benefits through flow regime changes; however, further work is required to quantify these. There was little overall impact on the CLLMM indicators under the BP-2800-RC scenario: some of the indicators worsened slightly, while some slightly improved.

Relaxing constraints delivered greater environmental benefits when combined with an extra 400 GL/y under a 3200 GL/y reduction in diversions. With constraints relaxed and a reduction in diversions of 3200 GL/y more flow indicator targets were achieved: for the River Murray, 17 out of the 18 ‘active management’ flow indicators were met, including the 80,000 ML/d for 30 days flow indicator for the Riverland–Chowilla floodplain hydrologic indicator site. As with the BP-2800-RC outcomes, relaxing constraints provided little additional benefit for the CLLMM under a BP-3200-RC scenario compared to benefits achieved in the BP-3200 scenario with constraints maintained.

The overall conclusion is that if constraints can be overcome there are likely to be increased ecological benefits for floodplains, particularly if combined with greater volumes of water recovery. Work done previously by MDBA shows increasing impacts on communities of water recovery greater than 2,750 GL/y, and this was an important consideration in MDBAs proposed Environmentally Sustainable Level of Take. As well, addressing constraints is outside MDBA’s mandate as many are managed under state arrangements and pertain to private land and will therefore require a significant investment, cooperation and commitment from governments, stakeholders and communities including an assessment of the costs and benefits.

Table of contents

List of tables

List of figures

1 Introduction

On 29 June 2012, the Murray–Darling Basin Ministerial Council requested that the Murray–Darling Basin Authority (MDBA) complete a ‘relaxed-constraints’ model scenario with a Basin-wide reduction in diversions of 3200 GL/y. The purpose of this scenario is to explore the flow regime changes and potential environmental benefits that would result if some major existing river operating constraints in the southern connected system were relaxed. This report documents the approach used and outcomes of that work.

1.1 Background

In November 2011 MDBA released the draft Basin Plan proposing an Environmentally Sustainable Level of Take (ESLT) of 10,873 GL/y—representing the recovery of 2,750 GL/y of water for the environment. The ESLT and water recovery amount were informed by a program of environmental flow assessments and modelling that commenced in 2009 and which was reviewed and refined through 2010 and 2011. In simplified terms the approach adopted by MDBA was to:

- develop Basin wide and subsidiary indicator site environmental objectives and targets. Examples of ecological targets include providing a flow regime to sustain flood dependent vegetation communities in a healthy condition and which supports the habitat and breeding requirements of waterbirds (refer the proposed Environmentally Sustainable Level of Take report, MDBA 2011c)
- determine environmental flow indicators to meet ecological targets for indicator sites. Flow indicators are expressed as a flow magnitude or volume, duration, timing and frequency as each of these components of the flow regime are important for achieving ecological targets. For example, overbank flows with a certain duration, frequency and timing are important for maintaining wetlands and river red gum communities. Site-specific flow indicators were developed drawing on scientific research, observations of outcomes from past flow events, and analysis of historical flow patterns (refer Basin Plan environmental water requirements reports, MDBA 2012a)
- model the capacity for selected water recovery options to achieve the frequency of flows associated with those flow indicators (refer Basin Plan modelling report, MDBA 2012b)
- use understanding of the links between flows and ecosystem responses to estimate the magnitude of improved ecological outcomes (this process is summarised in the proposed Environmentally Sustainable Level of Take report, MDBA 2011c).

In 2011, using this approach to inform the determination of the ESLT, the MDBA assessed the potential environmental outcomes associated with three ESLT options representing the recovery of 2400, 2800 and 3200 GL/y respectively. These three options were selected on the basis of past MDBA modelling, together with modelling undertaken by others (e.g. modelling undertaken to inform The Living Murray, Jones et al. 2002), and socio-economic assessments, as representing the range likely to achieve the requirements of the Water Act and management objectives for the Basin proposed by MDBA.

The modelling and associated assessments showed that 2400 GL/y was insufficient to achieve a number of key environmental objectives for the River Murray downstream of the Murrumbidgee junction (including the Coorong, Lower Lakes and Murray Mouth); while 3200 GL/y delivered few additional environmental benefits relative to the 2800 GL/y option.

One of the key insights gained through this work was the impact of river operating constraints on achieving certain environmental outcomes, particularly in the southern Basin. The modelling indicated 2,750 GL/y would be sufficient to achieve environmental objectives for in-stream processes, streamside vegetation, low-level wetlands, and low-level floodplain environments; but the benefits to higher level floodplains in the southern Basin were minimal. The 3,200 GL/y modelling option showed marginal improvements in some outcomes; but no significant improvement for mid- and high-level floodplain environments in the southern Basin. This was because river operating constraints were found to limit the ability to deliver sufficiently high flows to inundate mid- to high-elevation floodplains; thus outcomes such as watering vegetation communities like river red gum and black box woodland on these floodplains was unachievable, regardless of the SDL volume.

Within the boundaries of these constraints and the consideration of social and economic impacts, MDBA therefore proposed an SDL reflecting a 2,750 GL/y reduction in diversions.

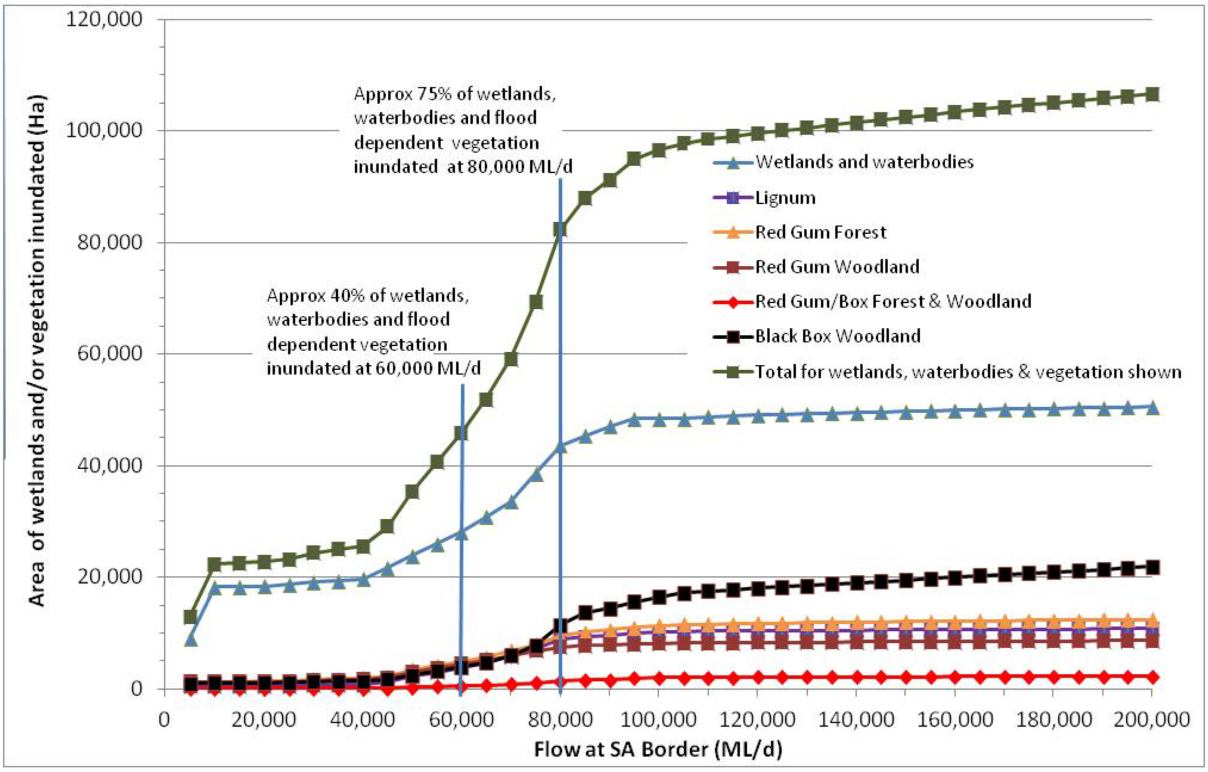
1.2 Potential benefits of overcoming constraints

River regulation and water use for consumptive purposes has significantly altered the flow regime of rivers across much of the Murray–Darling Basin. In lowland rivers such as the River Murray, the frequency at which floodplain and wetland habitats are inundated has significantly reduced; in many locations being now less than half what it was under pre-regulation conditions. Similarly, the length of time between flood events during dry times has grown substantially. In many locations it is now more than twice that experienced prior to regulation and diversion of river flow. This reduction in watering has had a significant impact on the health of those environments and across much of the Basin these habitats are transitioning from flood-dependent vegetation such as black box woodland to flood-tolerant communities such as samphire and chenopod shrublands.

Modelling undertaken to inform the draft Basin Plan showed it is possible to reinstate sustainable watering frequencies for in-stream processes, streamside vegetation, low-level wetlands, and low-level floodplain environments; but the frequencies required to sustain mid- to high-level floodplains in the southern Basin could not be achieved because of river operating constraints. The impact of constraints on the higher parts of the floodplain are particularly pronounced in the lower sections of the River Murray; where the cumulative effect of constraints, coupled with the cumulative effect of diversions throughout the Murray–Darling system are realised.

The potential benefits of overcoming river operating constraints are demonstrated in Figure 1, which shows the relationship between flow rate and the extent to which wetlands and dominant floodplain vegetation communities are inundated for the River Murray between the Darling River junction and Lock 1. Previous Basin Plan modelling (MDBA 2012b) indicated that under current river operating constraints it might be possible to reinstate a sustainable flow regime up to a flow rate of about 60,000 ML/d for the River Murray at the SA Border. Figure 1 indicates this flow would inundate around 40% of the wetlands and dominant vegetation communities in that reach of the River Murray between the Darling junction and Lock 1.

Figure 1: Relationship between inundation of wetlands and flood-dependent vegetation and flow in the River Murray between the Darling River junction and Lock 1.

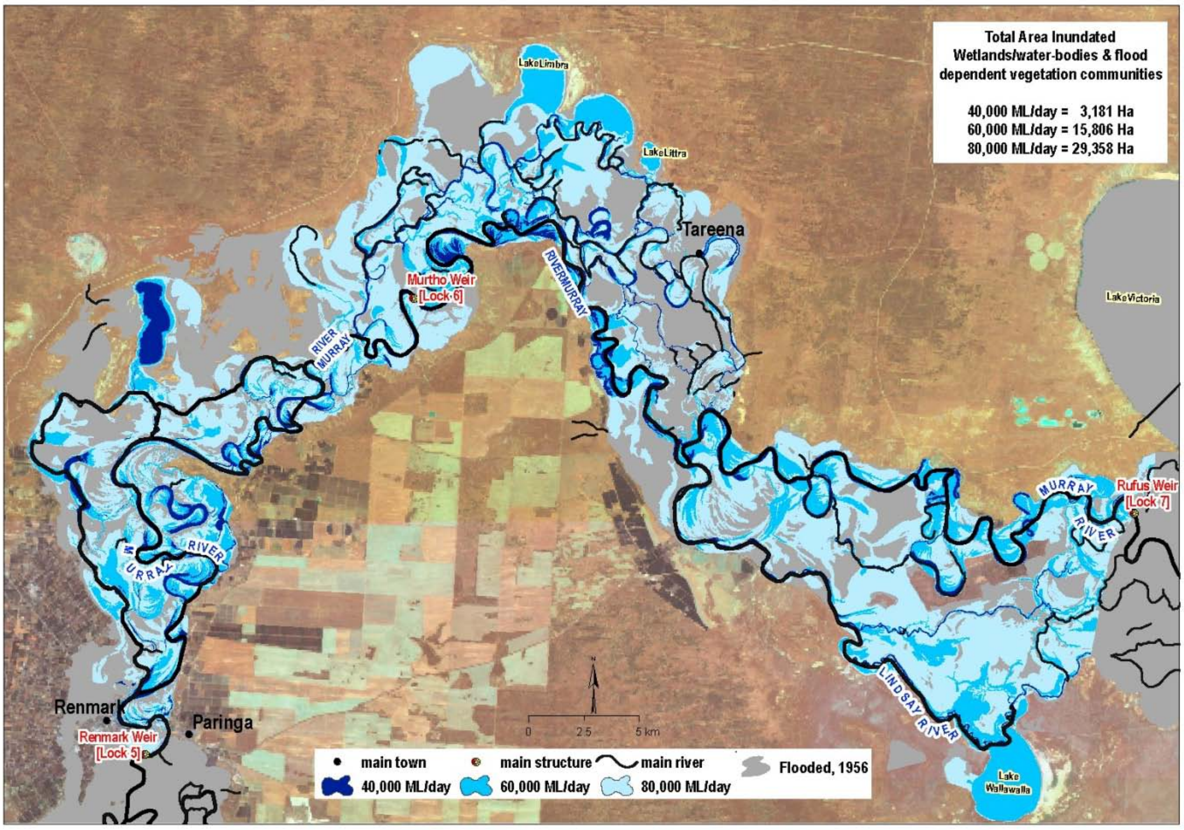


Note: The percentage of wetlands and vegetation communities inundated at 60,000 and 80,000 ML/d is expressed as a percentage of the area inundated at 200,000 ML/d. This does not represent the full extent of the River Murray floodplain (the 1956 flood event was over 300,000 ML/d); but areas above 200,000 ML/d are inundated very infrequently and are unlikely to support vegetation that requires frequent inundation.

Based on MDBA's preliminary assessment, it may be possible to overcome river operating constraints and increase the area of floodplain for which environmental water could be actively managed up to about 80,000 ML/d. There is a significant increase in the area of waterbodies and flood dependent vegetation that is inundated along the Lower River Murray downstream of the Darling River junction associated with an increase in flows from 60,000 ML/d to 80,000 ML/d (Figure 1 and Figure **2**). As such it would be desirable to be able to target the active delivery of environmental water up to this level.

However, this would require a commitment and significant investment from both state and federal governments and would be subject to further assessments, cost/benefit analysis (including assessments of any third party impacts) and extensive community consultation. Overcoming constraints to this extent would mean that the area that can be watered increases significantly—to about 75% of the wetlands and dominant vegetation communities of the floodplain. For this reach of the River Murray alone this would equate to more than 30,000 ha of additional benefit; and a similar scale of additional area would be inundated further upstream and downstream of this reach. This outcome could be of critical importance to the long-term sustainability of vegetation communities that inhabit the higher elevation areas of floodplain in our lowland rivers (such as black box woodlands). Environmental outcomes for higher parts of the floodplain above 80,000 ML/d are dependent on large, unregulated flows as river operators cannot readily manage water delivery to these parts of the floodplain as it would involve a much greater degree of flooding risk.

Figure 2: Map showing area of floodplain inundated between Locks 5 and 7 on the River Murray, with flow to South Australia of 40,000 to 80,000 ML/d.



1.3 Scope of this report

To identify the extent to which overcoming river operating constraints can achieve higher flows and better environmental outcomes, the MDBA has completed two 'relaxed constraints' model scenarios representing Basin wide water recovery of 2800 and 3200 GL/y respectively. These scenarios are referred to in this report as 'BP-2800-RC' and 'BP-3200-RC'. These new scenarios are an extension of the previous BP-2800 and BP-3200 scenarios that contributed to the determination of the proposed ESLT as described above (MDBA 2011c, 2012b).

These scenarios allow:

- a comparison of the previous BP scenarios (MDBA, 2012b) to these new model scenarios to allow assessment of the change in the flow regime and inferred environmental benefits resulting from the relaxation of flow constraints
- a comparison between the two relaxed-constraints scenarios to allow assessment of the change in flow regime resulting from a combination of constraint relaxation and the inclusion of an additional 400 GL/y for the environment.

This report documents the approach and results from this work, as outlined below:

1. The methodology for the modelling undertaken to relax key physical, operational and management constraints in the southern connected system is outlined. Two scenarios are tested based on a system wide water recovery of 2800 GL/y and 3200 GL/y. These two scenarios are further referred to as BP-2800-RC and BP-3200-RC. The water recovery from individual catchments is the same for the BP-2800 and BP-3200 scenarios previously reported in MDBA (2012b)
2. The modelling assumptions and strengths and limitations of the study are outlined.
3. Results and conclusions are reported with respect to improvements in environmental outcomes as a consequence of relaxing the constraints, as compared to the original modelling undertaken for the proposed Basin Plan (MDBA, 2012b).

The Basin Plan ESLT and modelling reports (MDBA 2011c and 2012b) provide a more detailed explanation of the basic modelling approach from which the impacts of constraint relaxation was tested.

2 Relaxation of constraints

Flows in the main rivers of the southern connected Murray–Darling Basin are generally managed (to the extent reasonable and practicable) according to the following objectives (in priority order):

1. Protect the security of the asset (i.e. infrastructure, such as a dam or a weir).
2. Maximise water availability against licensed entitlements.
3. Subject to meeting above two objectives, manage floods to limit damage to downstream communities and enhance environmental and amenity outcomes.

Because of the presence of a number of large dams, weirs and locks in the river system, both regulated and unregulated flows are attenuated. Flood mitigation is provided because of the potential to capture flow peaks in dams. This flood mitigation is sometimes enhanced by actively creating air space in storages via the operation of pre-releases. In addition to capturing peak flow in dams, river operators have also developed rules for releasing flows or mitigating floods, so as to minimise both serious and nuisance flooding downstream of dams. In many places, this has led to a maximum regulated flow release from dams which effectively keeps the river’s flow within a confined channel. This leads to suppression of the natural variability and consequently there is much less interaction between the river and its floodplain.

The operating rules for major storages, policies for water allocation and design of outlet capacities of the structures have generally been designed for meeting the demands of consumptive users. These various physical, operational and policy constraints have the effect of limiting the ability to provide environmental flows to the water-dependent ecosystems of the southern connected Basin, especially floodplain ecosystems.

In practice, any alteration to these constraints will be based on a flow constraint management strategy conducted with private landholder and community involvement. It is envisaged that the Constraints Management Strategy being included in the Basin Plan at the request of Ministerial

Council will set up a framework to investigate overcoming these issues. The types of actions that can overcome constraints include:

- obtaining flood easements
- building better accesses (roads, bridges)
- enhancing flood mitigation works (e.g. levies)
- increasing outlet capacity for some dams
- raising bridge heights (e.g. Mundarlo Bridge).

In general, managed environmental flows will rarely exceed minor flood levels; however, there are presently constraints approaching minor flood levels which would need to be addressed. Overcoming these constraints is a feasible option, but it will require a substantial level of investment by governments.

For the purposes of this study, MDBA focussed on relaxing eight key constraints in the southern connected system—which have been altered in the river system models to allow for potentially increased environmental flow rates. These constraints and the changes made are summarised in Figure 3 and Table 1, and details are provided below. Further information on the known constraints in the southern connected system and how they were included in the river system models is provided in Appendix A.

Figure 3: Map showing the location of the eight constraints relaxed for the purpose of this study.

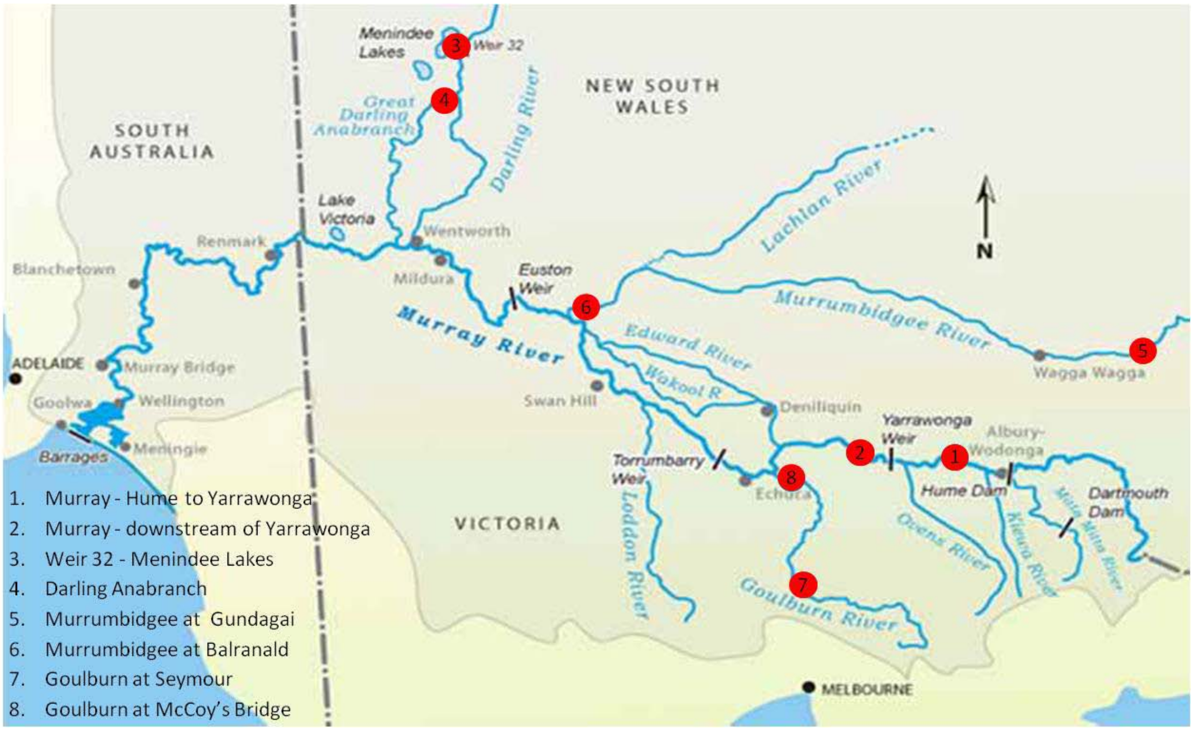


Table 1: Existing constraints applied in the models or demands for the proposed Basin Plan scenarios (MDBA, 2012b) and their increased values for the relaxed constraints scenarios.

Region	Location	Existing constraint (ML/d)	Relaxed constraint in model (ML/d)
Murray	Hume to Yarrawonga	25,000	40,000
	Downstream of Yarrawonga	22,000[1]	40,000
Lower Darling	Weir 32/Increase Menindee outlet capacity	9,300	18,000
	Darling Anabranch	Water flows into the anabranch at flows over 9,300 ML/d (no regulator)	Regulator added and closed above 9,300 ML/d when water is supplied from Menindee to meet environmental needs in the Murray
Murrumbidgee	Gundagai	30,000	50,000
	Balranald	9,000[2]	13,000
Goulburn	Seymour	12,000	15,000
	McCoy's Bridge	20,000[2]	40,000

Notes:

[1] Constraint was already relaxed to 40,000 ML/d in previous Basin Plan modelling (MDBA, 2012b); however, the Hume to Yarrawonga constraint of 25,000 ML/d was in place meaning the 40,000 ML/d limit could not be effectively utilised.

[2] Constraint is applied to tributary demands designed to contribute to achievement of downstream environmental water events in the River Murray.

River Murray

- **Hume to Yarrawonga**: the allowable regulated releases of environmental water from Hume Dam were increased in the model from 25,000 ML/d to 40,000 ML/d, to increase the capacity to meet downstream environmental flow objectives, particularly those requiring high flows to inundate the floodplain, but without exceeding minor flood level at Doctor's Point
- **downstream of Yarrawonga**: regulated releases of environmental water from Hume Dam were allowed to result in flows downstream of Yarrawonga up to 40,000 ML/d in the model, which is below the minor flood level downstream of Yarrawonga. Note that this change was also made in the original Basin Plan scenarios (MDBA 2012b), but given the Hume to Yarrawonga constraint of 25,000 ML/d was still in place, regulated flows downstream of Yarrawonga were effectively constrained in the earlier modelling scenarios.

Because of the high level of hydrologic connectivity in the southern system, environmental flow events on the River Murray are highly dependent on inflows from key tributaries. Thus, in addition to the changes in the Murray system, flow constraints in the Lower Darling, Murrumbidgee and Goulburn tributary systems have also been relaxed, specifically:

Lower Darling

- The outlet capacity at Menindee Lakes was increased within the modelling to allow up to 18,000 ML/d over Weir 32.

- A regulator was placed in the model on the Darling Anabranch, to prevent environmental releases above 9,300 ML/d from entering the anabranch when the intended delivery was for the River Murray. This allows more targeted and efficient delivery of water to the River Murray.

Murrumbidgee

- The maximum flow rate at Balranald included in demand timeseries for the downstream environmental for the River Murray was increased from 9,000 ML/d to 13,000 ML/d. The attenuation of flows through the lower Murrumbidgee floodplain only rarely produces flows over 9,000 ML/d at Balranald. However, it was envisaged that relaxing the constraint at Gundagai would allow slightly higher flows to be achieved at Balranald. Future modelling could test the maximum achievable flow at Balranald during a regulated event with upstream relaxation of constraints.
- The Gundagai Channel capacity was increased in the model from 32,000 ML/d to 50,000 ML/d.

Goulburn

- The maximum flow rate downstream of Eildon (at Seymour) was changed in the model from 12,000 ML/d to 15,000 ML/d
- The maximum flow rate at McCoy's Bridge Balranald included in demand timeseries for the downstream environmental for the River Murray was increased in the model from 20,000 ML/d to 40,000 ML/d. This flow rate is consistent with the highest flow rate at Shepparton recommended by DSE (2011) for Lower Goulburn floodplain environmental water requirements.

The Murray and Goulburn models were configured in a way that only allows the relaxing of these constraints during times of environmental water delivery—the flow constraints were maintained at their existing levels at all other times. Similarly, the regulator on the Darling Anabranch was closed only when there was a downstream environmental demand in the River Murray—to allow more water to pass down the Darling River to the Murray. At all other times the regulator remained open allowing flows to enter the Darling Anabranch (noting that explicit environmental demands for the Lower Darling are not included in the modelling).

The constraints relaxed in this study do not represent a relaxation of all constraints in each valley. Further improvements in environmental outcomes may be possible by relaxing more constraints or further relaxing the constraints listed above.

The removal of some of these constraints may lead to increased flow peaks further downstream, which may create nuisance flooding on privately held land. If this were to be pursued in reality (rather than in modelled scenarios), it is likely that governments would approach this by negotiation of easements. Assessing the downstream implications of managing higher flow rates from a flooding perspective will require detailed hydrodynamic modelling of the river system, and was not within the scope of this work.

If a significant package of work to address constraints were to be pursued, an extensive program to identify affected land (both within the target reaches and downstream) would need to be completed. In general, managed environmental flows will rarely exceed minor flood levels. It is feasible to overcome these constraints, but it will require a substantial investment by government.

3 Development of environmental demands for the model scenarios

The delivery of water in the models to meet environmental flow requirements was accomplished using demand timeseries. The demand series specifies an amount of water for each day of the 114 year modelling period. The daily demand timeseries was built from the historic flow record—to which specific periods of additional environmental water were added. Sometimes the additional flow was zero, and at other times it requested a volume which is expected to deliver an enhanced environmental outcome guided by identified 'environmental water requirements'.

The demand series were constructed using the same methods underlying those of the BP-2400, BP-2800 and BP-3200 scenarios. Accordingly, any identified possible improvements to the methods were not applied to the relaxed constraints scenarios to ensure the consistency required for robust assessment of the benefits of relaxing constraints. Demand timeseries were included in the models at several hydrologic indicator sites throughout the Basin. The construction of a demand series requires a number of steps: a full description can be found in the main Basin Plan Hydrologic Modelling Report (MDBA 2012b). This section contains a summary of this process.

3.1 Method summary

A hydrologic indicator site approach underpins the inclusion of environmental demands in the hydrological models. This involves assessment of environmental water requirements for different parts of the flow regime. Environmental water requirements specified at hydrologic indicator sites are intended to represent the broader environmental flow needs of river valleys or reaches; and thus the needs of a broader suite of ecological assets and functions.

Mid- to high-flow events (such as freshes and overbank flows) comprise the volumetrically dominant component of the environmental water requirements; hence the greatest effort was dedicated to demand series representing this component of the flow regime[1]. Freshes and overbank flows are defined by distinct flow events. As a result, these environmental water requirements are generally specified in terms of a required volumetric flow threshold and duration, and these specifications have defined the flow patterns requested by the demand series in the models. For the Basin Plan an extensive series of target flow events were identified—believed to be desirable to obtain healthy rivers across the Basin. The relationship between these requested events and environmental outcomes are detailed in the EWR reports (e.g. MDBA 2012a), and are summarised in Table 2.

The fresh and overbank flow demand series were created using the Environmental Event Selection Tool (EEST). A full description can be found in the Hydrologic Modelling Report (MDBA 2012b). The

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[1] Baseflow (or low flow) demand series have been included in the models; however, these series have generally been allocated a lower priority in the modelled environmental water allocation process (MDBA 2012b).

MDBA adopted an approach to determining environmental flows that aims to reproduce particular natural flow events that are believed to be environmentally significant. As such, the predominant mode for including environmental flow events in the modelling is to partly 'reinstate' these events to meet target peaks and durations at certain locations.

In summary, this tool allows the selection of events for inclusion in the demand series, where these events occurred under without-development conditions, but are no longer present because of changes such as flow regulation or consumptive use (as represented in the baseline model). The selection of these events is subject to an annual Basin Plan Environmental Watering Account (BP-EWA) volume, which limits the number of events that can be selected in any year to the volume in the annual account (subject to a simple carryover provision). When included in the model, the demand series requests water from an upstream storage to deliver a set of chosen events, designed to address shortfalls in various ecologically significant components of the flow regime.

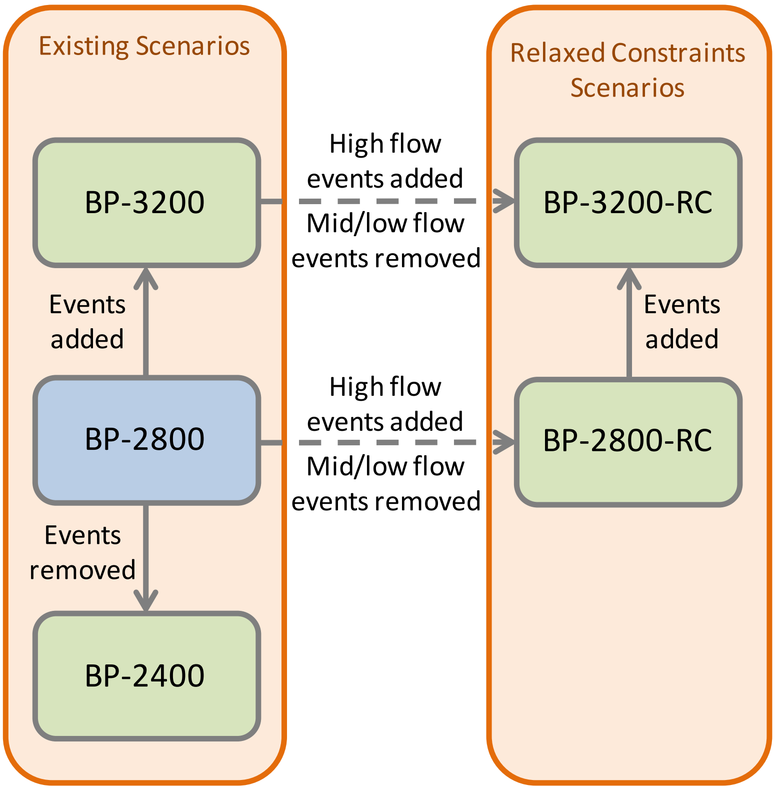
3.2 Building the relaxed constraints model scenarios from previous scenarios

The environmental watering strategies developed for the BP-2800 and BP-3200 scenarios were modified for the relaxed constraints scenarios. Through the modelling process it was found that the relaxation of constraints allowed a greater volume of water to be released from storage to deliver on existing environmental flow demands (those in the original BP-2800 and BP-3200 scenarios). Put another way: existing river operating constraints were limiting the delivery of demands in the previous model scenarios, and relaxing constraints allowed those demands to be more fully delivered. Without a change to the environmental watering strategy, this would have delivered additional volumes of environmental water exceeding the amount available to the environment in some years and negatively impacting on the reliability of supply to consumptive users.

Consequently, the selection of environmental watering events required adjustment, and this adjustment adopted an emphasis on reducing the water dedicated to low-flow events and adding it to high-flow events where possible. This changed strategy implies a greater emphasis on high-flow events to inundate a larger proportion of the floodplain at an increased frequency, consistent with a river management situation where there is greater ability to deliver high flows. This reallocation process was conducted largely without affecting the achievement of other flow targets as represented in the existing BP-2800 and BP-3200 scenarios; and baseflows and freshes demands remained unchanged from the previous model scenarios (except for the CLLMM/freshes demand which changed marginally).

The starting point for the environmental flow demands were those identified in the original BP-2800 and BP-3200 scenarios. The demands were then modified to select events which caused broader floodplain inundation—to test how much the easing of constraints allowed the delivery of these larger peak flows (Figure 4).

Figure 4: Schematic diagram outlining the connection between environmental demand sequences for each scenario, where the original BP-2800 sequence is marked in blue.



To achieve this altered environmental watering strategy, events were removed preferentially from those low- to mid-flow indicators for which:

- the frequency of successful events exceeded the low uncertainty frequency in the existing constraints scenario
- the frequency of successful events was in the low uncertainty-high uncertainty frequency range and it was known from the existing constraints scenario that there would be a number of bonus events (bonus events occur as a result of upstream or downstream watering actions rather than deliberate environmental watering at that indicator site).

By using these rules, this reallocation process was conducted largely without affecting the achievement of low- to mid-flow targets as represented in the existing BP-2800 and BP-3200 scenarios; and baseflows and freshes remained unchanged.

Furthermore, to minimise third party impacts, the additional high-flow events included in the two sequences were preferentially those which represented the least change to the existing flow regime (as represented in the baseline scenario). The indicators targeted for additional events are listed below:

- Barmah–Millewa Forest: 35 GL/d for 30 days
- Gunbower–Koondrook–Perricoota Forest: 40 GL/d for 60 days
- Hattah Lakes: 70 GL/d for 42 days
- Hattah Lakes: 85 GL/d for 30 days

- Riverland–Chowilla Floodplain: 60 GL/d for 60 days
- Riverland–Chowilla Floodplain: 80 GL/d for 30 days.

The changed number of events included in the demand series for each indicator is summarised in Table 2. (Note that these are not results, but are inputs to the modelling process—see Sections 5.1 and 5.2 for the results.)

The demand timeseries were created external to the modelling framework, and this process does not allow the environmental water use to be tracked prior to their inclusion in the models. The EEST provides an estimate of the use; however, the model outputs provide a more accurate measurement. Hence, a number of iterations were undertaken to create a final set of environmental demands for both the BP-2800-RC and BP-3200-RC scenarios which satisfied the environmental use criterion and did not impact on the reliability of consumptive users, as demonstrated through storage behaviour.

Early iterations of the BP-2800-RC demands showed that while it was possible to move equivalent volumes of water from lower flow to higher flow events, there was a negative impact on long-term water use. This was a direct consequence of the constraint relaxation process represented in the modelling, which allowed environmental water to be released from storage at higher peak rates than in the BP-2800 scenario, and led to a decrease in the amount of water available in storages for consumptive use. To maintain a long-term environmental water use profile consistent with that in the BP-2800 scenario (and therefore not impact long-term consumptive reliability profiles), a large number of mid-to-low flow events were removed from the demand series and only a small number of mid-to-high-flow events were added (two 35,000 ML/d events at Barmah–Millewa Forest (Table 2).

With the additional 400 GL/y available under the BP-3200-RC scenario, it was possible to add a number of higher flow events to the demand series, along with some lower flow events at Gunbower–Koondrook–Perricoota Forest to preserve the frequency obtained in BP-3200 (Table 2). The reason for this is further discussed in the results section. The removal of lower flow events in BP-3200-RC mimicked the pattern of removal for the BP-2800-RC demands.

Table 2: The number of environmental events requested in the BP-2800-RC and BP-3200-RC scenarios, including the change in requested events compared to the BP-2800 and BP-3200 sequences (grey indicators did not have environmental events requested).

Hydrologic indicator site	Flow indicator	# Requested Events: BP-2800-RC scenario	Change from BP-2800 scenario	# Requested Events: BP-3200-RC scenario	Change from BP-3200 scenario
Mid-Murrumbidgee Wetlands	26,850 ML/d for 45 days				
	26,850 ML/d for 5 days	11	0	14	-2
	34,650 ML/d for 5 days	13	0	13	0
	44,000 ML/d for 3 days	11	0	17	+2
	63,250 ML/d for 3 days	9	0	9	0
Lower Murrumbidgee Floodplain	175,000 ML over 3 mths	3	-12	3	-12
	270,000 ML over 3 mths	7	-13	7	-13
	400,000 ML over 4 mths	17	-7	17	-7
	800,000 ML over 4 mths	11	-1	11	-1
	1,700,000 ML over 5 mths	0	-5	0	-8
	2,700,000 ML over 10 mths	1	-3	1	-6
Barmah–Millewa Forest	12,500 ML/d for 70 days	27	0	27	0
	16,000 ML/d for 98 days	9	-10	9	-11
	25,000 ML/d for 42 days	9	-3	9	-5
	35,000 ML/d for 30 days	11	+2	11	0
	50,000 ML/d for 21 days				
	60,000 ML/d for 14 days				
	15,000 ML/d for 150 days	26	0	30	+4
Gunbower–Koondrook–Perricoota Forest	16,000 ML/d for 90 days	44	-1	57	+12
	20,000 ML/d for 60 days	30	0	34	+2
	30,000 ML/d for 60 days	7	-1	8	-5
	40,000 ML/d for 60 days	7	0	15	+3
	20,000 ML/d for 150 days	22	-1	29	+3
Hattah Lakes	40,000 ML/d for 60 days	10	-6	10	-7
	50,000 ML/d for 60 days	19	-3	19	-7
	70,000 ML/d for 42 days	7	0	13	0
	85,000 ML/d for 30 days	4	0	11	+4
	120,000 ML/d for 14 days				
	150,000 ML/d for 7 days				
Riverland–Chowilla Floodplain	20,000 ML/d for 60 days				
	40,000 ML/d for 30 days	17	-8	17	-8
	40,000 ML/d for 90 days	8	-2	8	-6
	60,000 ML/d for 60 days	10	0	14	0
	80,000 ML/d for 30 days*	6	0	10	+2
	100,000 ML/d for 21 days				
	125,000 ML/d for 7 days				

* While the Hydrologic Modelling Report (MDBA 2012b, pg 34) reported that 8 events were requested for the 80 GL/d flow indicator at Chowilla in the BP-2800, this should have been reported as 6 events requested. Similarly, the Hydrologic Modelling Report reported that 10 events were requested for the 80 GL/d flow indicator at Chowilla in BP-3200, this should have been reported as 8 events requested.

4 Modelling methodology

To be able to make meaningful comparisons between the various scenarios, the modelling was performed using the same methodology as applied to the original Basin Plan scenarios described in MDBA (2012b). This means that any possible improvements to the modelling methods that have been identified since the original Basin Plan scenarios were completed were not applied to the relaxed constraints scenarios presented in this report. A short summary of the methodology, building on the inputs outlined in Sections 2and 3, is provided below.

4.1 River Murray and Lower Darling system

Model scenarios with relaxed constraints were based on the same level of reduction in diversions to the original Basin Plan scenarios. Therefore, reduction in irrigation entitlements was maintained as per the original Basin Plan scenarios.

Environmental demands were included at Yarrawonga, Torrumbarry, Euston and SA Border for high-flow water requirements. There were baseflow components included on the River Murray at the SA border and Burtundy on the Darling River. The demands at the SA Border also included freshes and additional water for the CLLMM site. A further description of the demands is given in Section 3.

As described in Section 2, key constraints were relaxed to enhance the delivery of the environmental demands. The relaxed constraints allowed releasing of more water from the head storage when needed, which changed storage behaviour slightly. To maintain the similar storage level compared to the original Basin Plan scenarios, the environmental demands were iteratively changed to minimise impact on irrigation reliability. At the final iteration, irrigation demands were scaled to achieve targeted diversions.

4.2 Murrumbidgee River system

Modelling was carried out for 593 GL/y and 715 GL/y reductions in irrigation diversions in the Murrumbidgee, which correspond to the BP-2800 and BP-3200 model scenarios respectively. These reduction levels include a 320 GL/y reduction for in-valley Murrumbidgee environmental requirements. The remainder is a pro-rata estimate of the Murrumbidgee contribution to the shared reduction in the southern connected system.

To keep the total licence entitlements in the model constant, the entitlement volumes were reduced on a proportional basis and included in a new ‘environmental user’. This new user was subject to the same rules (i.e. carryover) as per other extractive users in the system.

The model was adjusted to implement relaxation of constraints as described in Section 2. Environmental demands were included (as minimum flow demands) at Narrandera, Maude and Balranald. These accounted for the travel time between the site and the confluence of the Murrumbidgee and Tumut Rivers. A detailed description of these demands is given in Section 3.

After inclusion of all demands, total irrigation diversions for the valley were limited to the targeted level of reduction, thus restricting consumptive use to the prescribed level. The total demand volume (Coorong component) and total irrigation diversions were iteratively altered until the final sequence (storage volumes close to baseline and diversions at the prescribed level of reduction) was achieved. Total storage level (Burrinjuck plus Blowering) was also checked for consistency with the long-term average baseline storage level. For full details of the modelling methodology, refer to Section 5.9.6 of MDBA (2012b).

4.3 Goulburn River system

Model scenarios were carried out for 458 GL/y and 552 GL/y reductions in diversions in the Goulburn, which correspond to the BP-2800 and BP-3200 model scenarios respectively. These reduction levels include a 344 GL/y reduction for in-valley environmental requirements. The remainder is a pro-rata estimate of the Goulburn contribution to the shared reduction in the southern connected system.

The irrigation and licensed private diversion entitlements were reduced (excluding stock and domestic and urban entitlements); based on required reduction in diversions, as described in MDBA (2012b). The volumes by which entitlements were reduced were added to the environmental water account from which environmental demands are delivered.

In the first instance, demands were reduced by the same factor as applied to the entitlements. After inclusion of the environmental demands, the demands (as well as the supplement from the Loddon to the Waranga Western channel) were further adjusted to match the targeted level of reduction in diversions.

For the two scenarios with relaxed constraints, the model was adjusted so that:

- the Eildon releases were based on a channel capacity constraint at Seymour of 15,000 ML/d, rather than 12,000 ML/d
- demands were included for McCoy's Bridge; which is a combined demand for the Lower Goulburn Floodplain, the Murray and the baseflows in the reach. As described in Section 3, these demands were adjusted from the original BP-2800 in order to achieve more high-flow events in the Lower Murray. Hereby, the 20,000 ML/d limit that was applied to the downstream demands in the BP-2800 and BP-3200 scenarios was relaxed to 40,000 ML/d.

The baseflow demands for upper reaches in the Goulburn remained unchanged from the demands used in the original Basin Plan scenarios (MDBA, 2012b). The Basin Plan model also included a rule that allows for additional Coorong demands in years that flows for the Coorong would be relatively low and when the volume in the environmental carry-over account was over 180 GL (MDBA, 2012b).

5 Results – River Murray and Lower Darling system

The interpretation of modelling results should be viewed within context. The modelling scenarios represent only one possible scenario to achieve environmental outcomes based on the targeted use of environmental water, combined with relaxation of some key constraints in the southern connected system. The modelling results are indicative of a possible hydrologic regime; however, a range of potential alternative scenarios could be tested with different assumptions and principles regarding water recovery, water accounting, environmental water use and river operating constraints.

Sections 5.1 and 5.2 present results of the modelling showing changes in flow regime associated with a Basin-wide reduction in diversions of 2800 GL/y and 3200 GL/y combined with relaxation of key constraints in the southern connected system. As described in the hydrologic modelling report (MDBA 2012b), there are many ways to analyse and present hydrological data. The modelling results presented herein focus on the ability to achieve flow indicators at hydrologic indicator sites. Ecological outcomes are inferred based on an understanding of the relationship between site-specific flow indicators and achievement of ecological targets. In addition, more subtle changes in the flow regime, not detected by the flow indicators, are also discussed as these marginal improvements may have important ecological benefits. In Section 5.3 the results of a more detailed dry spell analysis are presented.

Results for the Murrumbidgee and Goulburn systems have been reported in Appendix B.

5.1 Results - BP-2800-RC

5.1.1 Environmental results

A summary of environmental results for the River Murray and Lower Darling for the BP-2800-RC scenarios is provided in Box 1.

Box 1: Summary of River Murray and Lower Darling results of the BP-2800-RC scenario.

Summary of BP-2800-RC results: River Murray and Lower Darling

- limited improvement to the achievement of flow indicators; with the exception being the achievement of a *high-flow target* in the Upper Murray (Barmah–Millewa Forest 35,000 ML/d for 30 days) with expected benefits for mid-level floodplain vegetation communities such as river red gum forest and woodland
- increased *flow peak and duration* for inundation events in the southern system and increased average number of *high-flow days per year* in the Lower Murray, both of which can be related to positive ecological benefits in terms of area of floodplain inundated
- no marked and/or consistent change in achievement of salinity and flow indicators for the Coorong, Lower Lakes and Murray Mouth, or in shortfalls for in-channel baseflows.

If the overall results in terms of flow indicator achievement remained unchanged, minor differences in the flow indicator frequency of events between the BP-2800 and BP-2800-RC scenarios were not explored. Clearly, relaxing of the constraints is a key factor in explaining some of these minor differences in frequency; however, there are other potential factors. These include:

- changes to the environmental demands at the site, i.e. as described in Section 3, some environmental events were removed in the BP-2800-RC
- changes to the environmental demands at an upstream or downstream site, i.e. as described in Section 3, some environmental events were removed in the BP-2800-RC which will have consequences by changing the delivery of 'other successful events' as described in MDBA (2012b)
- minor changes to the storage behaviour leading to changes in spills, which can be seen as changes in 'baseline events lost' as described in MDBA (2012b).

The relative importance of these different factors varies both at site scale (between sites) and flow indicator scale (between individual flow indicators at a site). Given this complexity, the detail of which factor (or potentially multiple interacting factors) explains the minor differences observed between the BP-2800 and BP-2800-RC scenarios was not explored for every flow indicator at every site.

Barmah–Millewa Forest

Seven flow indicators were developed for the Barmah–Millewa Forest to achieve site-specific ecological targets (MDBA 2012a). Consistent with the BP-2400, BP-2800 and BP-3200 scenarios, environmental demand timeseries targeted delivery of water to only five of these indicators (corresponding to flows between 12,500 and 35,000 ML/d). The remaining two indicators (associated with flows between 50,000 and 60,000 ML/d) were considered to be beyond the capacity for managed delivery under existing conditions, and also conditions under the relaxed constraints scenario.

Similar to the BP-2800 scenario, the target frequency of events (expressed as the proportion of years containing a successful event) was achieved under the BP-2800-RC scenario for the following indicators (Table 3):

- 12,500 ML/d for 70 days
- 16,000 ML/d for 98 days
- 25,000 ML/d for 42 days
- 15,000 ML/d for 150 days.

These flows are associated with outcomes for wetlands, near channel vegetation, low-level floodplain communities (such as river red gum forest) and conditions suitable for breeding of colonial nesting waterbirds.

The most significant difference at this site was found for the 35,000 ML/d for 30 days flow indicator, which is associated with mid-level floodplain communities (such as river red gum woodland). The target proportion of years for this indicator was not achieved under any of the original Basin Plan scenarios;

Table 3: Flow indicator achievement for the Barmah–Millewa Forest under without development, baseline, BP-2800 and BP-2800-RC conditions.

			Without development	Baseline	BP-2800[*]		BP-2800-RC[*]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with a successful event	Number of years with a successful event	Number of years with a successful event
Flow Event - threshold, duration, season (as gauged on the River Murray at Yarrawonga Weir)		Target proportion of years with a successful event – high to low uncertainty						
1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	87%	50%	95	83%	93	82%
2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	66	58%	59	52%
3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	50	44%	52	46%
4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33 - 40 %	53%	24%	34	30%	38	33%
5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25 - 30 %	39%	18%	18	16%	16	14%
6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20 - 25 %	33%	14%	13	11%	12	11%
7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	44%	11%	43	38%	44	39%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

however, it has been achieved under the BP-2800-RC scenario. This is a consequence of two factors: relaxing constraints and changes to the demand timeseries for this flow indicator.

In the relaxed constraints scenario, existing flow constraints downstream of Hume Dam (25,000 ML/d) were raised to 40,000 ML/d, allowing increased capacity to deliver regulated flows in the reach to Yarrawonga Weir, which are then passed downstream of the weir to the Barmah–Millewa Forest. The relaxed constraints allow for control over the duration of events at this higher level, such that events which were ordered but not delivered successfully in the BP-2800 scenario, are successfully delivered in the BP-2800-RC scenario.

Gunbower–Koondrook–Perricoota Forest

Five flow indicators were developed for Gunbower–Koondrook–Perricoota Forest to achieve site-specific ecological targets (MDBA 2012a). Flow events associated with all five flow indicators were included in the environmental demand series for all scenarios.

Overall, some flow indicator frequency results at this site reduced as a result of constraint relaxation (and the associated changes to the environmental water delivery strategy), whereas others increased (Table 4). These frequency changes are not expected to impact the overall achievement of environmental outcomes.

Consistent with the results for the BP-2800 scenario, under the relaxed constraints scenario the target event frequency was achieved for the 30,000 ML/d indicator; and was not achieved for the 16,000 ML/d indicator, the 40,000 ML/d indicator, and the 150-day 20,000 ML/d indicator. The relaxation of constraints improved the number of events associated with the highest flow indicator at this site (the proportion of years containing a 40,000 ML/d for 60 days event increased from 18% to 20%). In contrast, the two flow indicators associated with relatively low threshold and long duration events (16,000 ML/d for 90 days, and 20,000 ML/d for 150 days) decreased slightly in frequency compared to the BP-2800 scenario (by one and two events respectively; Table 4).

However, the number of events associated with the shorter duration (60 days) 20,000 ML/d indicator decreased from 60% to 59%; hence the target frequency (60%) is no longer satisfied. This reduction is not associated with the events explicitly requested at this site—22 of the 32 (69%) requested events were delivered in the BP-2800 scenario, and this increased to 23 (out of 30, or 77%) in the BP-2800-RC scenario. This increase suggests that the relaxation of constraints improves the ability to deliver these flow events deliberately. Instead, the reduction is related to the number of ‘other successful events’, which are associated with demand series requesting flows for other environmental events (either at this site or at another upstream/downstream site). The number of these events decreased from seven (BP-2800) to five (BP-2800-RC) which, when combined with the additional delivered event, resulted in an overall reduction of one event over the 114-year period. In practice, one of the removed ‘other successful events’ could be restored through a extension (of a few days) of environmental releases from an upstream storage; hence this small reduction does not represent a significant reduction in expected environmental outcomes associated with this flow indicator.

Table 4: Flow indicator achievement for the Gunbower–Koondrook–Perricoota Forest under without development, baseline, BP-2800 and BP-2800-RC conditions.

Flow Indicator			Without development	Baseline	BP-2800*		BP-2800-RC*	
	Flow Event - threshold, duration, season (as gauged on the River Murray at Torrumbarry Weir)	Target proportion of years with a successful event – high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful l event
1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	86%	31%	78	68%	76	67%
2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60 - 70 %	87%	34%	68	60%	67	59%
3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33 - 50 %	60%	25%	43	38%	41	36%
4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25 - 33 %	39%	11%	21	18%	23	20%
5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	43%	7%	31	27%	29	25%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

Hattah Lakes

Six flow indicators were developed for Hattah Lakes to achieve site-specific ecological targets (MDBA 2012a). Flow events associated with the first four flow indicators were included in the environmental demand series at this site. The two highest threshold indicators for flows of 120,000 ML/d and 150,000 ML/d were considered to be beyond the capacity for managed delivery, both under existing conditions and the relaxed constraints scenario; hence requests for these higher peaks were not included in the demand series.

Consistent with the BP-2800 scenario, the BP-2800-RC scenario achieved the target frequencies expressed as proportion of years for the following indicators (Table 5):

- 40,000 ML/d for 60 days
- 50,000 ML/d for 60 days.

These flows are associated with outcomes for wetlands, near channel vegetation and low level floodplain communities such as river red gum forest.

Overall, the relaxation of constraints demonstrated little change in the Hattah Lakes flow indicator results in the BP-2800-RC scenario. There is no change to the achievement of flow indicator target frequencies; and there is, at most, a 1% difference in the proportion of years compared to the BP-2800 scenario.

As outlined in Section 3, in practice, the relaxation of constraints is expected to result in an altered environmental water delivery strategy. Therefore, some of the lower threshold events were removed from the demand series to provide greater volume for the higher flow events. Thus, the frequencies associated with lower-threshold indicators (flows of 40,000 to 50,000 ML/d) were reduced, but are still meeting the target frequency. The volume of water in the high flow regime (70,000 to 85,000 ML/d) increased because of constraint relaxation (even though the demand series for these events were unchanged); however, this increased volume was not reflected in the flow indicators.

This emphasises the relative coarseness of the environmental flow indicators, which do not always detect ecologically-significant changes in the flow regime. This site is a fair distance from storages, with little re-regulating capacity in between. Therefore, timing the environmental flow releases from Murrumbidgee, Goulburn and Hume Dam so as to reach Euston at the same time is a challenge. The amount of attenuation in the flow peaks varies depending on the antecedent conditions and thus improvements in high-flow targets (within the 10% tolerance level) did not occur. However, the number of days with desirable high flows increased.

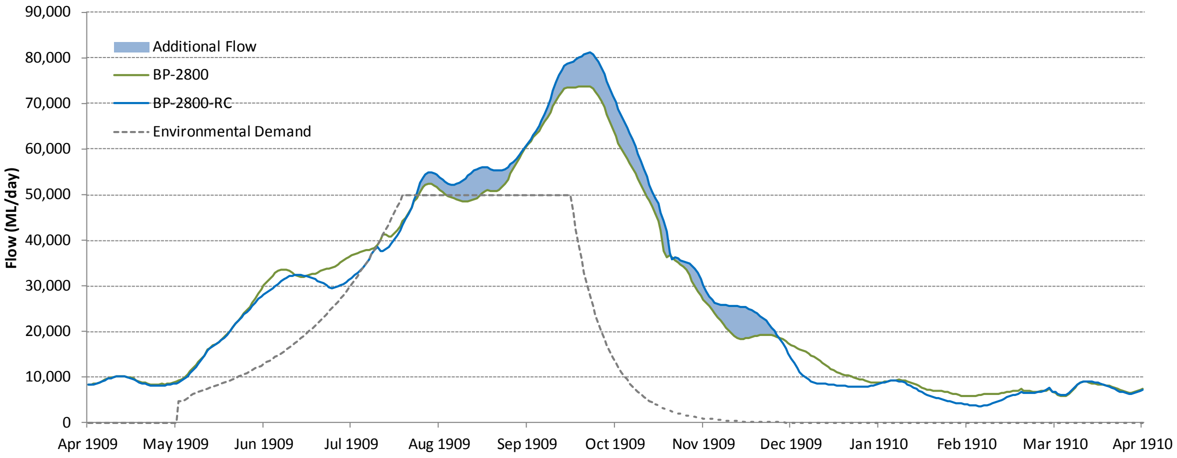
This additional water delivered in the higher section of the flow regime supplemented events already present in the BP-2800 scenario, rather than added new events. An example of this effect is shown in Figure 5. This event (50,000 ML/d for 60 days) was successful under both scenarios; however, the relaxation of constraints increased the duration of the flow event above 70,000 ML/d and significantly added to the peak flow (raised from 74,000 to 81,000 ML/d). These increases correspond to the additional inundation of approximately 3,000 ha of flood-dependent vegetation between Euston Weir (Lock 15) and Wentworth (Lock 10).

Table 5: Flow indicator achievement for Hattah Lakes under without development, baseline, BP-2800 and BP-2800-RC conditions.

			Without development	Baseline	BP-2800[*]		BP-2800-RC[*]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the River Murray at Euston Weir)		Target proportion of years with a successful event – high to low uncertainty						
1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40 - 50 %	67%	30%	53	46%	51	45%
2	50,000 ML/d for a total duration of 60 days (with a min duration of 7 consecutive days) between Jun & Dec	30 - 40 %	47%	19%	36	32%	36	32%
3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20 - 33 %	38%	11%	20	18%	19	17%
4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20 - 30 %	33%	10%	15	13%	15	13%
5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14 - 20 %	23%	8%	9	8%	9	8%
6	150,000 ML/Day for 7 consecutive days between Jun & May	10 - 13 %	17%	5%	6	5%	6	5%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

Figure 5: An example of changes to the delivery of a requested environmental event for the Hattah Lakes hydrologic indicator site, due to constraint relaxation in the model. The flow indicator targeted by this flow event is 50,000 ML/d for 60 days.



Riverland–Chowilla Floodplain

Seven flow indicators were developed to achieve site-specific ecological targets for the Riverland–Chowilla Floodplain and in-channel flows within the River Murray (MDBA 2012a). Four of the seven flow indicators were included in the environmental demand series. Events of 100,000 ML/d and 125,000 ML/d at the Riverland–Chowilla Floodplain were considered to be beyond the capacity for managed delivery, under both existing conditions and under the relaxed constraints scenario. Therefore, requests for these higher peaks were not included in the demand series. Also, the in-channel fresh flow indicator of 20,000 ML/d for 60 days was not finalised in time to allow for its inclusion in the original BP-2800 modelling process, and was therefore also excluded from this BP-2800-RC demand series, to maintain consistency.

Similar to the results for Hattah Lakes described above, the flow indicators at the Riverland–Chowilla Floodplain demonstrated little change because of the relaxation of constraints (Table 6). Consistent with the BP-2800 scenario, the relaxed constraints scenario achieved the target frequencies expressed as proportion of years for the following indicators:

- 40,000 ML/d for 30 days
- 40,000 ML/d for 90 days
- 60,000 ML/d for 60 days.

These flows are associated with outcomes for wetlands, near channel vegetation and low-level floodplain communities.

For only one flow indicator the frequency changed from successful (under BP-2800) to unsuccessful under the BP-2800-RC scenario. This was the 20,000 ML/d for 60 days indicator, which is associated with in-channel outcomes, particularly for native fish. It reduced from being achieved in 72% of years in the BP-2800 scenario to 68% under the BP-2800-RC scenario.

Table 6: Flow indicator achievement for the Riverland-–Chowilla Floodplain under without development, baseline, BP-2800 and BP-2800-RC conditions.

			Without development	Baseline	BP-2800[1]		BP-2800-RC[1]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the River Murray at SA Border)		Target proportion of years with a successful event – high to low uncertainty						
1	20,000 ML/d for 60 consecutive days between Aug & Dec	72 - 80 %	89%	43%	82	72%	77	68%
2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50 - 70 %	80%	37%	69	61%	66	58%
3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33 - 50 %	58%	22%	41	36%	39	34%
4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25 - 33 %	41%	12%	28	25%	29	25%
5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17 - 25 %	34%	10%	16[2]	14%[2]	15	13%
6	100,000 ML/d for a total duration of 21 days between Jun & May	13 - 17 %	19%	6%	6	5%	7	6%
7	125,000 ML/d for a total duration of 7 days between Jun & May	10 - 13 %	17%	4%	5	4%	5	4%

[1] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

[2] These numbers were erroneously reported as 15 and 13% respectively in the Hydrologic Modelling Report (MDBA 2012b).

The decrease in frequency of years that this target was met in the BP-2800-RC scenario is explained by the lack of an explicit environmental demand timeseries for the 20,000 ML/d for 60 days flow indicator. Achievement of the target frequency is therefore dependent on ‘other successful events’; that is, demands that fully achieved the flow criteria (at other sites located upstream and/or downstream) despite these events not being requested in the demand timeseries for the specific indicator site. As described in Section 3, changes to the environmental demands at other sites (upstream and/or downstream) resulted in a reduction in the number of ‘other successful events’ contributing to achievement of the target frequency in the BP-2800-RC scenario (28 events, compared to 33 events in the BP-2800 scenario).

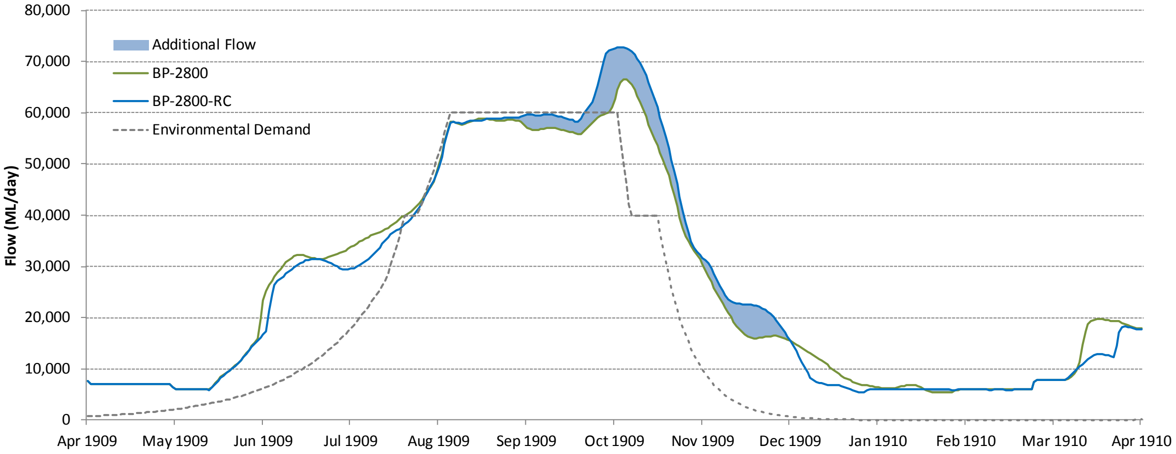
This represents an unintended outcome of modifying the environmental demands and does not reflect a change due to relaxing constraints. It is not considered to represent a significant reduction in expected environmental outcomes based on consideration of two factors:

- Firstly, if an explicit environmental demand was developed for this indicator; the volumetric requirement would be relatively small and therefore likely to be feasible with a 2800 GL/y water recovery volume.
- Secondly, the storage levels in Menindee Lakes and Lake Victoria were consistently higher than baseline in both the BP-2800 and BP-2800-RC scenarios. As such, there is scope for additional demands at the Riverland–Chowilla floodplain to draw down Menindee Lakes and Lake Victoria in a more optimal manner while achieving multiple objectives without compromising reliability of supply for consumptive users.

For other Riverland–Chowilla floodplain flow indicators there were only minor differences between the BP-2800 and BP-2800-RC scenarios and none of the changes are significant in terms of achieving target frequencies. Compared to the BP-2800 scenario, some volume used for low- to mid-flow events was redistributed in the model towards the high-end of the flow regime. The event frequencies for the two 40,000 ML/d indicators therefore reduced, and the number of successful 60,000 ML/d for 60 days events increased (the proportion of years remained unchanged at 25%, but there was one extra event in the BP-2800-RC scenario).

Under baseline conditions, the average number of days per year with flows in excess of the 60,000 ML/d threshold was 19.5. By including 2800 GL/y of water recovered for the environment, this value increased to 25.4 days/y in the BP-2800 scenario, an increase of 30%. By further including the relaxation of constraints in the BP-2800-RC scenario, this value rose to 26.9 days, an increase of 38% from baseline. An example of this increase can be seen in Figure 6, where the number of days with a flow greater than 60,000 ML/d has doubled (from 13 to 26 days).

Figure 6: An example of changes to the delivery of a requested environmental event for the Riverland–Chowilla hydrologic indicator site in 1909, due to modelled constraint relaxation. The flow indicator targeted by this flow event is 60,000 ML/d for 60 days for the Riverland–Chowilla floodplain.



There was a decline of 1% in the frequency of 80,000 ML/d for 30 days events as a result of relaxing constraints, with neither scenario attaining the high uncertainty target. The same number of events was requested in each scenario. The relaxation of constraints improved the peak flow and duration of the requested 80,000 ML/d events, although these subtle changes in the flow regime were not detected by the flow indicator. For example, Figure 7 shows a modelled event which is considered successful in both scenarios—yet the relaxation of constraints marginally improved both the peak and duration of flows greater than 80,000 ML/d. Figure 8 shows an event in 1951 which did not meet the required flow criteria in either scenario—yet the relaxation of constraints significantly increased the flows during the event. Thus, while the constraints relaxation improved the environmental benefits of many of these events, these changes were not detected by the flow indicators.

Figure 7: An example of changes to the delivery of a requested environmental event for the Riverland–Chowilla hydrologic indicator site in 1958, due to modelled constraint relaxation. The flow indicators targeted by this flow event is 60,000 ML/d for 60 days and 80,000 ML/d for 30 days.

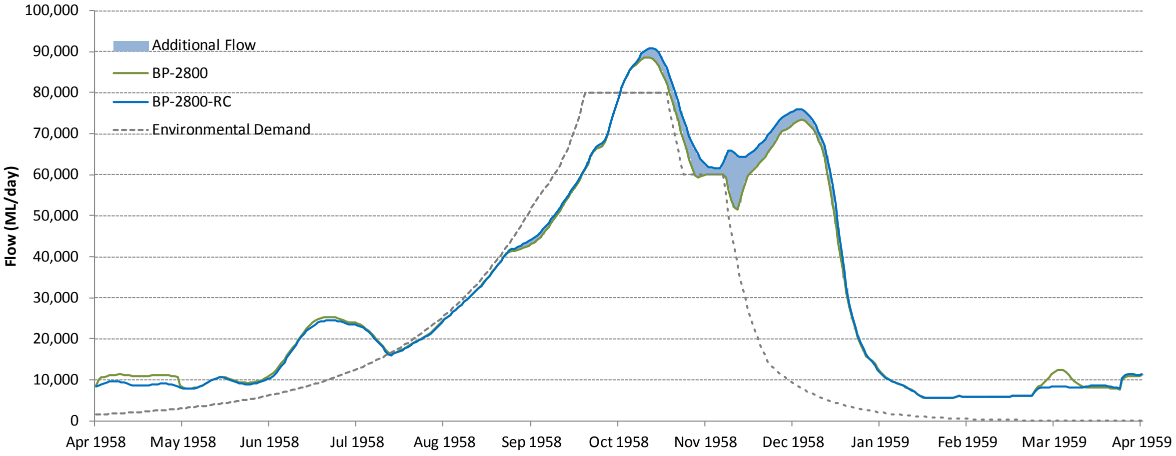
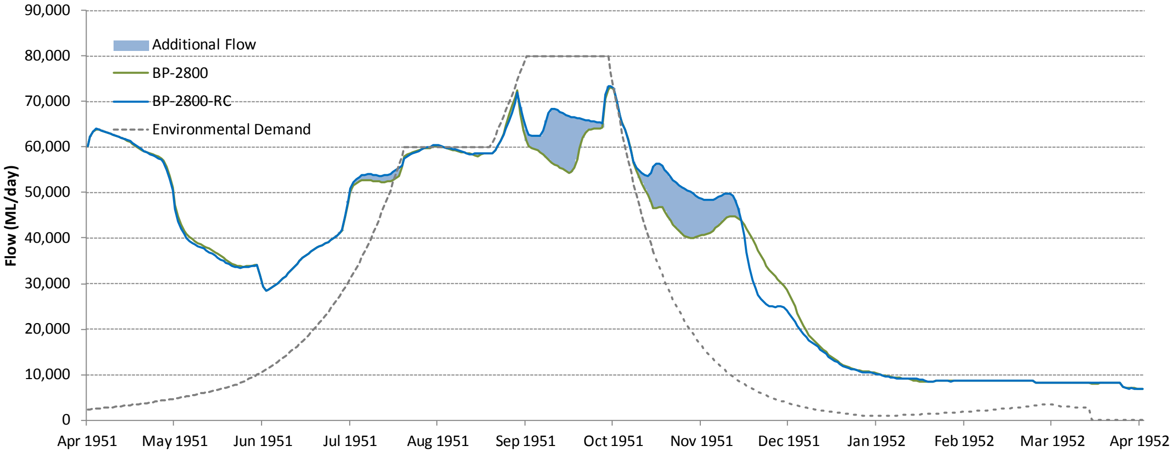


Figure 8: An example of changes to the delivery of a requested environmental event for the Riverland–Chowilla hydrologic indicator site in 1951, due to modelled constraint relaxation. The flow indicators targeted by this flow event is 60,000 ML/d for 60 days and 80,000 ML/d for 30 days.



Lower Darling and Edward-Wakool River systems

Consistent with the methodology applied in the BP-2800 and BP-3200 scenarios, demand series were not developed for these two indicator sites. Thus, any changes in environmental indicator results at these two sites are a consequence of changes to watering actions at upstream or downstream sites. The results (Table 7, Table 8 and Appendix C) show only minor changes compared to the BP-2800 scenario, and a full description of the potential to meet these targets in practice is given the Hydrological Modelling Report (MDBA 2012b).

Given the lack of a demand sequence targeted at the Lower Darling indicators, Menindee Lakes supplied water downstream in accordance with the Murray–Darling Basin Agreement. The relaxation to operating capacity tested in the Lower Darling was 18,000 ML/d; however, four of the five indicators at this site are associated with flows of 20,000 ML/d or above. As with all the constraints altered in the modelling, further work would be required to determine if constraints could be relaxed to 20,000 ML/d or above in the Lower Darling.

It is also important to note that the operation of the Darling Anabranch regulator, as modelled for the constraints relaxed scenarios, could be different in practice. In the model it was assumed that the operation of such a regulator would be based on environmental watering objectives, whereby the regulator would remain open if the objective was to achieve ecological outcomes in the anabranch and would be closed to prevent water entering the anabranch when the intended delivery was for the River Murray.

The modelling did not include explicit environmental demands for the Lower Darling River and anabranch. However, the Menindee Lakes storage levels were consistently higher than baseline in the relaxed constraints scenarios (see Figure 11). Under these conditions the modelling suggests that, subject to some changes to the provisions of the Murray–Darling Basin Agreement, this additional volume of water could be used in a more optimal manner to achieve multiple environmental objectives in the Lower Darling and Lower Murray.

Table 7: Flow indicator achievement for the Edward-Wakool River System under without development, baseline, BP-2800 and BP-2800-RC conditions.

			Without development	Baseline	BP-2800*		BP-2800-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Edward River at Deniliquin)		Target proportion of years with a successful event – high to low uncertainty						
1	1,500 ML/Day for a total duration of 180 days (with a minimum duration of 1 consecutive day) between Jun & Mar	99 - 100 %	75%	96%	108	95%	109	96%
2	5,000 ML/Day for a total duration of 60 days (with a minimum duration of 7 consecutive days) between Jun & Dec	60 - 70 %	82%	39%	72	63%	70	61%
3	5,000 ML/Day for a total of 120 days (with a minimum duration of 7 consecutive days) between Jun & Dec	35 - 40 %	52%	22%	41	36%	40	35%
4	18,000 ML/Day for a total of 28 days (with a minimum duration of 5 consecutive days) between Jun & Dec	25 - 30 %	39%	15%	18	16%	17	15%
5	30,000 ML/Day for a total of 21 days (with a minimum duration of 6 consecutive days) between Jun & Dec	17 - 20 %	28%	12%	12	11%	12	11%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Table 8: Flow indicator achievement for the Lower Darling Floodplain under without development, baseline, BP-2800 and BP-2800-RC conditions.

			Without development	Baseline	BP-2800[*]		BP-2800-RC[*]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Darling River at Weir 32)		Target proportion of years with a successful event – high to low uncertainty						
1	20,000 ML/Day for 30 consecutive days between Jun & May	14 - 20 %	27%	10%	13	11%	13	11%
2	25,000 ML/Day for 45 consecutive days between Jun & May	8 - 10 %	14%	8%	9	8%	9	8%
3	45,000 ML/Day for 2 consecutive days between Jun & May	7 - 10 %	11%	8%	9	8%	9	8%
4	7,000 ML/Day for 10 consecutive days between Jun & May	70 - 90 %	95%	51%	68	60%	68	60%
5	17,000 ML/Day for 18 consecutive days between Jun & May	20 - 40 %	49%	18%	28	25%	29	25%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

Coorong, Lower Lakes and Murray Mouth

A combination of barrage flow and salinity indicators were specified for the Coorong, Lower Lakes and Murray Mouth (CLLMM) hydrologic indicator site (refer to MDBA 2012a). The first seven indicators monitor salinity behaviour in the Coorong. The final two indicators for barrage flows can be related to salinity and water levels within the Coorong and Lower Lakes, salt export volumes and influence Murray Mouth opening. As described in MDBA (2012b), there is an iterative approach to incorporating environmental demands for the CLLMM into the modelling. The second iteration includes a demand at the South Australian border designed to meet in-channel baseflow and fresh requirements, which will contribute to meeting CLLMM requirements. This does not, however, represent an explicit environmental demand to meet CLLMM salinity and flow indicators; and instead achievement of indicators is dependent on accruing the benefits of return flows from upstream water deliveries.

Similar to the BP-2800 scenario, MDBA considers that while the results show some departure from the desired targets, all flow and salinity indicators were effectively achieved in the BP-2800-RC scenario (Table 9) (within the range of uncertainty inherent in the modelling and the eco-hydrologic understanding).

Salinity indicators in the Coorong southern lagoon were met in both the BP-2800 and BP-2800-RC scenarios, with some small improvements in both average and maximum salinity when constraints were relaxed.

Salinity indicators in the Coorong northern lagoon were also effectively met, but did show small changes compared to the BP-2800 scenario. The average salinity target of 20 g/L was met under the BP-2800-RC. The corresponding average salinity target was technically unmet in the BP-2800 scenario (with a result of 21 g/L); however this is a modest departure. Maximum salinity indicators for the Coorong northern lagoon showed some increase in the BP-2800-RC scenario (61 g/L) compared to the BP-2800 scenario (56 g/L). Given the uncertainty around the salinity requirements of *Ruppia megacarpa* on which targets are based, and the target number of days above 50 g/L being for a total of only three to four months over the entire 114-year modelling period, the results for both the BP-2800 and BP-2800-RC scenarios are considered acceptable and unlikely to have implications for the long-term health of the Coorong.

While the overall results remained unchanged, relatively small changes were observed in the BP-2800-RC scenario for various CLLMM indicators, which are explained by changes to the environmental watering patterns. These changes resulted in an altered distribution of barrage flows, both within and between years. This is partly shown by the small reduction (1%) in the 3-year rolling average barrage flows greater than 2,000 GL/y in the BP-2800-RC scenario, compared to BP-2800. The small changes to the pattern of inflows to the Coorong, Lower Lakes and Murray Mouth did not result in major changes to the indicators selected by the MDBA; however it is possible that the changes to the patterns of river inflow may result in subtle changes in environmental outcomes not reflected by the indicators.

The impact of an altered environmental watering strategy on CLLMM indicators is further illustrated by Coorong salinities. For example, the proportion of years that salinity in Coorong southern lagoon is less than 100 g/L increased from 96% in the BP-2800 scenario to 99% in BP-2800-RC (Table 9). This difference is largely explained by the 100 g/L threshold no longer being exceeded in the BP-2800-RC scenario in the 2006–07 and 2007–08 water years. In the BP-2800-RC scenario, additional demands were included in 2006–07 and 2007–08 at the South Australian border to meet in-channel baseflow and fresh requirements with subsequent benefits for the CLLMM (190 GL and 319 GL additional demand in 2006–07 and 2007–08 respectively). The reductions in Coorong salinity over the 2006–2008 period are also shown in Appendix D. While these reductions in salinity are likely to be ecologically significant for mitigating periods of stress experienced by the keystone *Ruppia* species, the modelled changes can be more closely related to the altered environmental demand strategy than a response to constraints being relaxed.

In terms of Murray Mouth openness, the exceedence curve shown in Figure 9 illustrates a significant improvement in Murray Mouth bed depths, compared to baseline conditions for both the BP-2800 and BP-2800-RC scenarios over the 114 year modelling period. There is, however, no discernible difference in Murray Mouth bed levels (m AHD, below sea level) between the BP-2800 and BP-2800-RC scenarios (Figure 9).

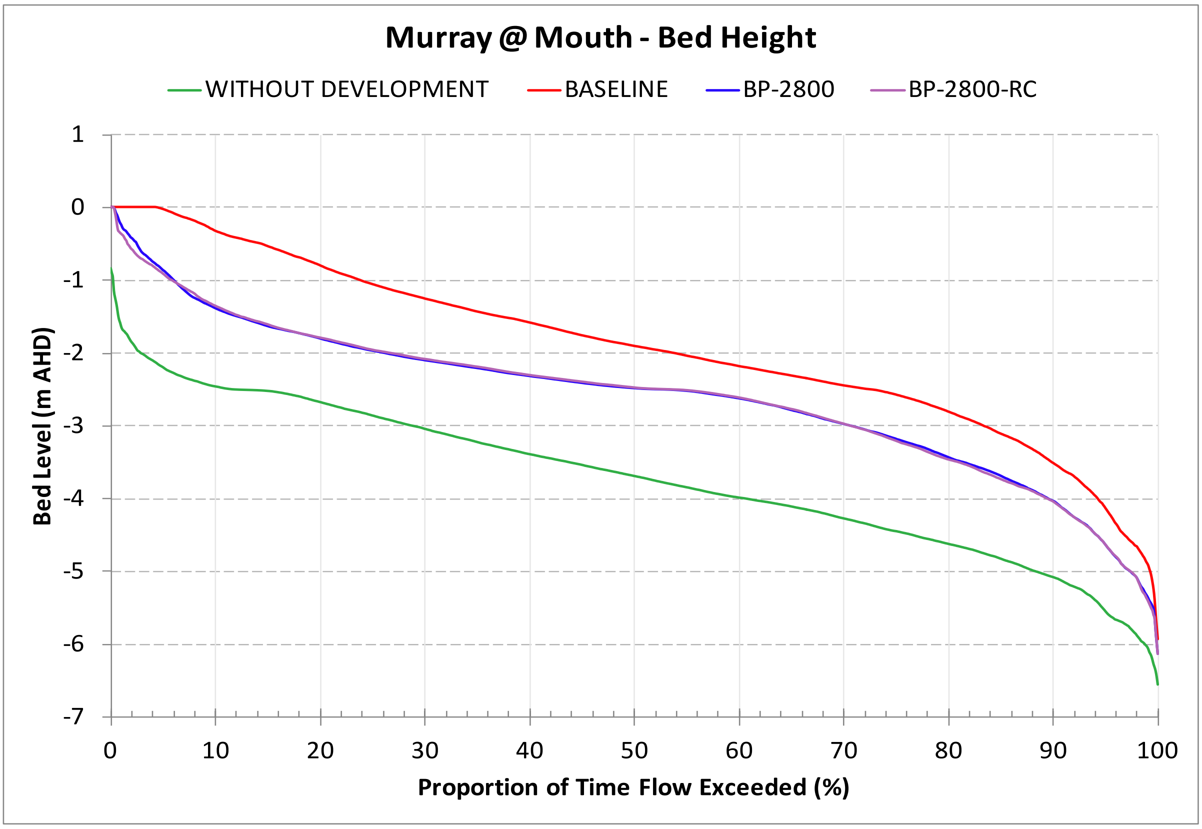
Appendix D shows figures of Murray Mouth bed levels, barrage flows, Lower Lakes water levels and Coorong salinity levels for the period July 2000 to June 2009, which incorporate the Millennium Drought. These illustrate the ability of both the BP-2800 and BP-2800-RC scenarios to mitigate the impacts of the Millennium Drought. The differences between the two 2800 GL scenarios were relatively small and variable. At different times over the 10 year period the relaxed constraints scenario showed marginally improved bed levels, barrage flows, Lower Lake levels and Coorong salinity levels relative to the BP-2800 scenario; however, at other times these indicators showed marginal declines. As outlined above, these subtle differences are more closely linked to changes in the environmental demand strategy, rather than being a direct response to relaxing constraints.

The modelled long-term salt export from the Basin is estimated to be 1.95 million tonnes per year under the BP-2800-RC scenario. This slight reduction from 1.96 million tonnes per year in the BP-2800 scenario is explained by the small decrease in average barrage flows, as identified in Table 11. As discussed in MDBA (2012b), these salt load export estimates did not include projected future increases in salt mobilisation; thus, it is considered that, on average, more than 2 million tonnes of salt would be exported per year from the Basin under both scenarios.

Table 9: Flow and salinity indicator achievement for the Coorong, Lower Lakes and Murray Mouth site under without development, baseline, BP-2800 and BP-2800-RC scenarios.

Indicator	Target	Without development	Baseline	BP-2800	BP-2800-RC
Average salinity (g/L) in Coorong southern lagoon over model period	less than 60 g/L	24	62	44	43
Maximum salinity (g/L) in Coorong southern lagoon over model period	less than 130 g/L	67	291	119	111
Max period (days) salinity in Coorong southern lagoon is greater than 130 g/L	0 days	0	323	0	0
Proportion of years salinity in Coorong southern lagoon < 100 g/L	greater than 95%	100%	82%	96%	99%
Average salinity (g/L) in Coorong northern lagoon over model period	less than 20 g/L	12	29	21	20
Maximum salinity (g/L) in Coorong northern lagoon over model period	less than 50 g/L	49	148	56	61
Max period (days) salinity in Coorong northern lagoon is greater than 50 g/L	0 days	0	604	75	114
Proportion of years 3 year rolling average barrage flow greater than 1,000 GL/y	100%	100%	91%	99%	99%
Proportion of years 3 year rolling average barrage flow greater than 2,000 GL/y	greater than 95%	100%	79%	98%	97%

Figure 9: Murray Mouth bed level exceedance curve for without development, baseline, BP-2800 and BP-2800-RC scenarios.



Baseflows

Baseflows were included in the environmental demands series for the River Murray at the South Australian border (Flow to SA) and at Burtundy on the Darling River. The achievement of baseflows was assessed in terms of long-term average shortfalls on the baseflow targets: a shortfall of zero indicates that the target was completely met (Table 10).

The results show that changes to baseflows as a result of relaxation of constraints were generally small. This is consistent with the expectation that altering the constraints would have the greatest impact at the high-end of the flow regime.

Table 10: The shortfall (in GL/y) on the baseflow targets in the River Murray under the baseline, BP-2800, and BP-2800-RC scenarios.

Site	Baseline	BP-2800	BP-2800-RC
401010 – Swampy Plains River at Khancoban	0	0	0
401201 – River Murray at Jingellic	0	0	0
409017 – River Murray at Doctor's Point	59.6	21.1	24.0
409025 – River Murray at Yarrawonga Weir	8.4	3.4	3.0
409207 – River Murray at Torrumbarry Weir	89.9	16.9	26.3
414200 – River Murray at Wakool River junction	32.8	2.7	4.2
414203 – River Murray at Euston Weir	54.5	0.2	0.0
425010 – River Murray at Wentworth	99.1	1.2	1.4
426200 – River Murray Flow to SA	141.4	3.9	5.6
426532 – River Murray at Wellington	325.2	50.3	56.0
425007 – Darling River at Burtundy	46.4	4.2	4.2

5.1.2 Hydrological results

To ensure that the modelling scenario was consistent with the targeted water recovery volume, a key part of the modelling process was to check the pattern of both the reduction in diversions and storage levels, relative to baseline conditions. This step was necessary to ensure that the process of developing environmental demands using an environmental account outside of the models did not impact on the long-term reliability of other water users, or result in a reduction in diversions that exceeded the water recovery target.

Table 11 presents a summary of the Murray system water balance showing that annual diversions for the BP-2800-RC scenario were maintained at an almost identical level to the BP-2800 scenario, achieving 1177 GL/y reduction in diversions compared to the 1178 GL/y target. The target reduction in diversions was achieved through an iterative process of including environmental demands and scaling irrigation demands. Murray inflows increased slightly (10 GL/y) in the BP-2800-RC scenario, mainly because of increased inflows from Murrumbidgee. However there was a slight reduction in outflows in the BP-2800-RC scenario that corresponds to increased losses associated with delivery of higher flows when constraints are relaxed.

Table 11: Water balance for the Murray system for the without development, baseline, BP-2800 and BP-2800-RC scenarios.

	Without development	Baseline	BP-2800	BP-2800-RC
Inflows:				
NSW	5,940	3,317	3,975	3,984
Victorian	5,782	3,866	4,367	4,368
Shared	4,664	5,200	5,200	5,200
Total inflows	**16,386**	**12,383**	**13,542**	**13,552**
Diversions:				
NSW Murray	0	1,696	1,180	1,180
NSW Lower Darling	0	55	40	41
Victorian	0	1,654	1,161	1,162
South Australia	0	665	511	511
Total diversions	**0**	**4,070**	**2,892**	**2,893**
Loss*	**4,008**	**3,225**	**3,494**	**3,510**
Outflow	**12,377**	**5,088**	**7,156**	**7,148**

* Loss includes system loss, unattributed loss in the model and change in storage.

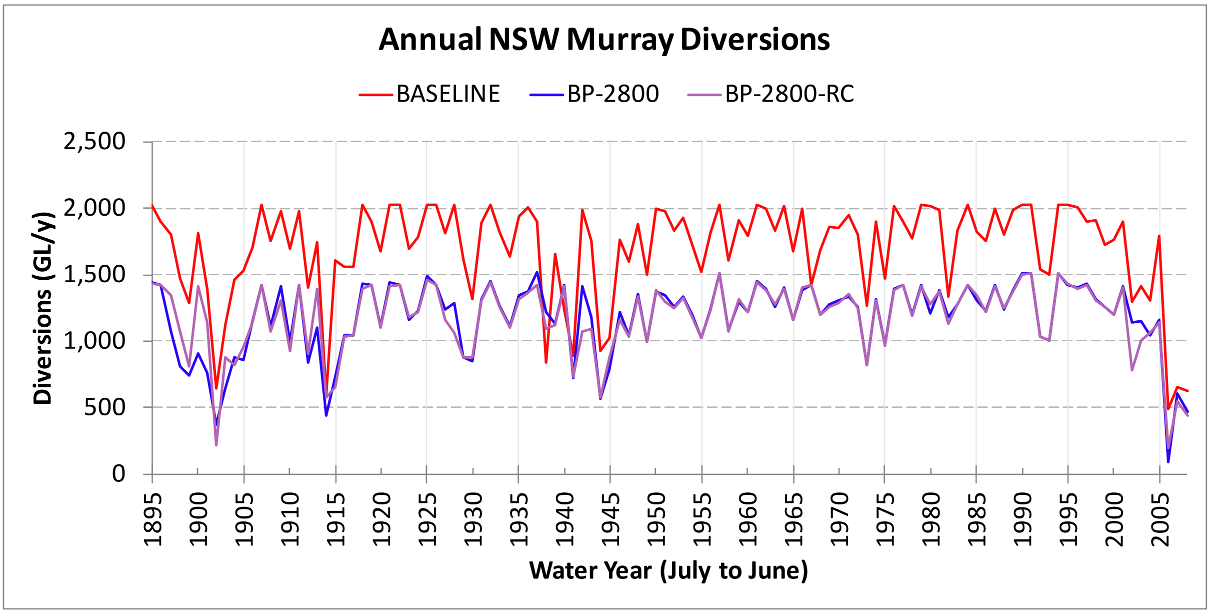
Modelling results for the BP-2800 scenario were previously described in MDBA (2012b), therefore the focus of this section is the BP-2800-RC scenario.

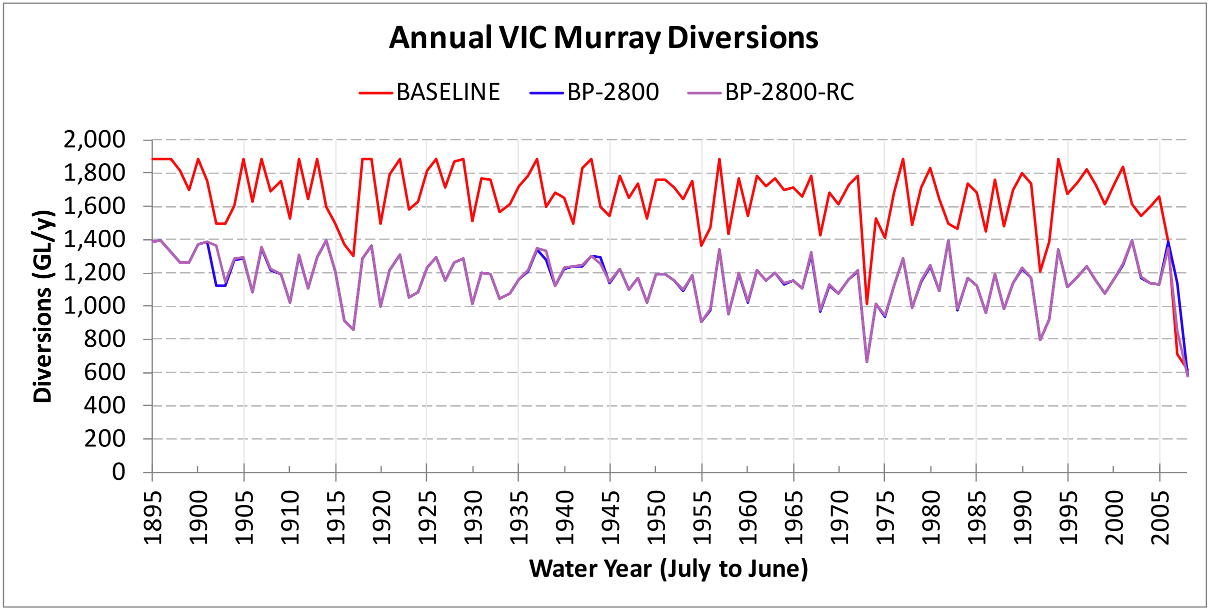
Figure 10, Figure 11 and Figure 12 show differences in annual diversions, major storages and end-of-system flow between the BP-2800 and BP-2800-RC scenarios. Figure 10 shows that the patterns of the two scenarios closely match and reflect baseline conditions. Only NSW diversions show a small degree of variation in the pattern of diversions, which can be addressed through changes to water allocation policies as noted in MDBA (2012b).

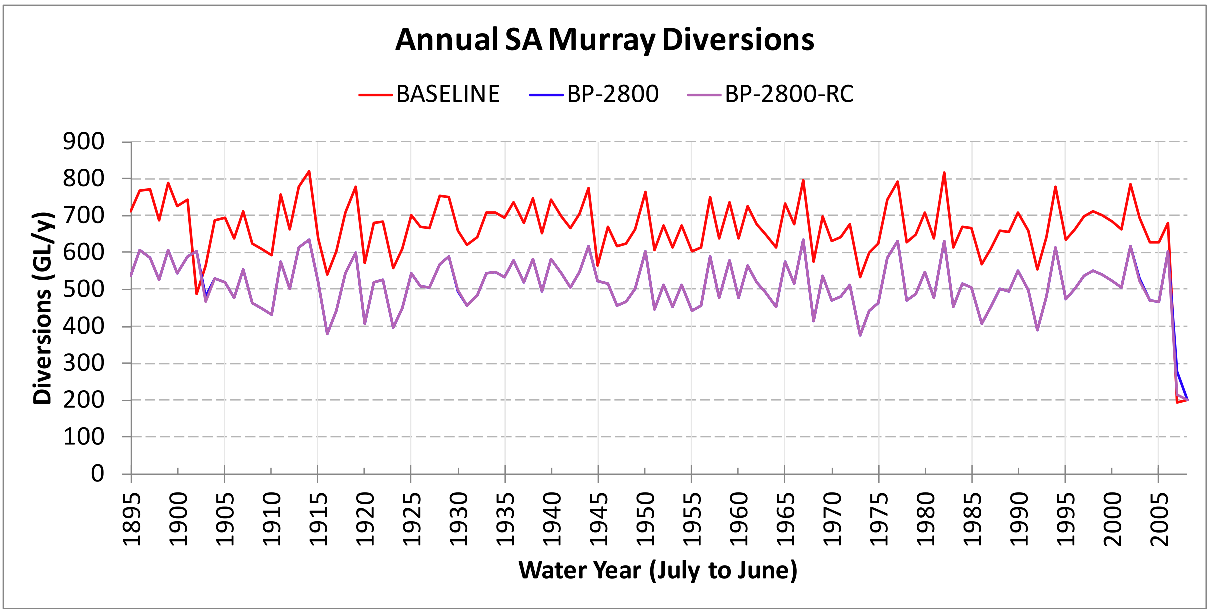
The combined annual average storage volumes in Dartmouth and Hume Dam for the BP-2800, BP-2800-RC and baseline scenarios were similar. This was despite some inter-annual variability because of some differences in the timing of environmental demands compared to the baseline pattern of consumptive demand. In contrast, and consistent with other Basin Plan modelling scenarios, storages in the Lower Murray (Lake Victoria and Menindee Lakes) were consistently higher than levels under baseline conditions.

Long-term average barrage flows marginally reduced (by about 12 GL/y) in the BP-2800-RC scenario (Table 11); however, there was no discernible difference in annual barrage flows (Figure 12).

Figure 10: Annual diversions in the River Murray System (for New South Wales, Victoria, South Australia and the Lower Darling) for the baseline, BP-2800 and BP-2800-RC scenarios.






Annual SA Murray Diversions
BASELINE
BP-2800
BP-2800-RC
Diversions (GL/y)
0
100
200
300
400
500
600
700
800
900
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

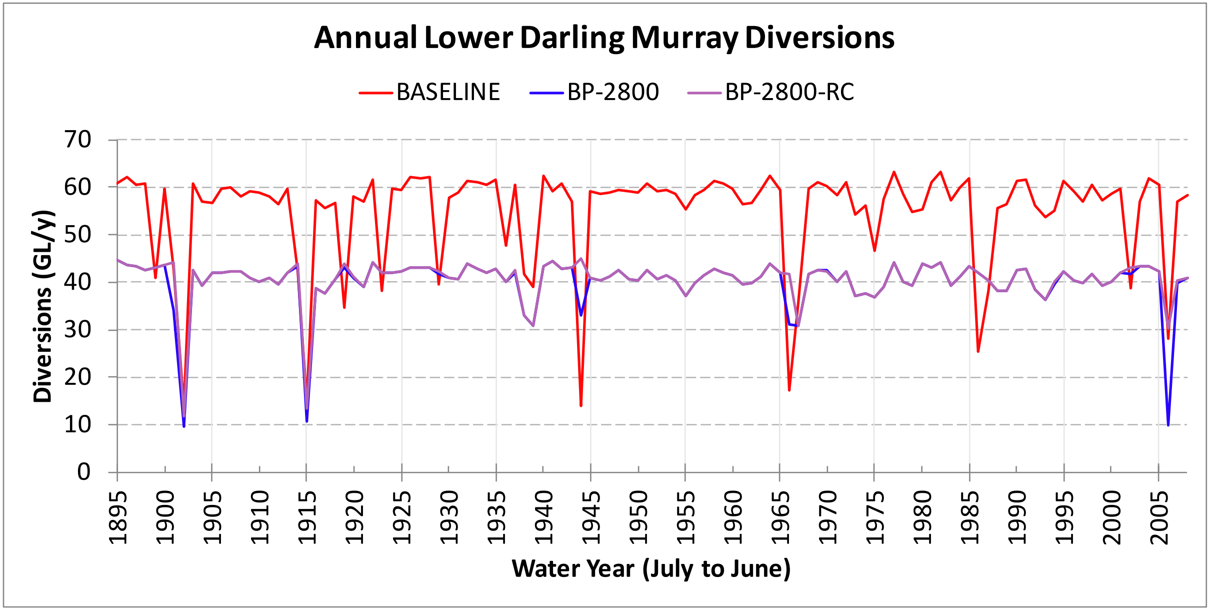
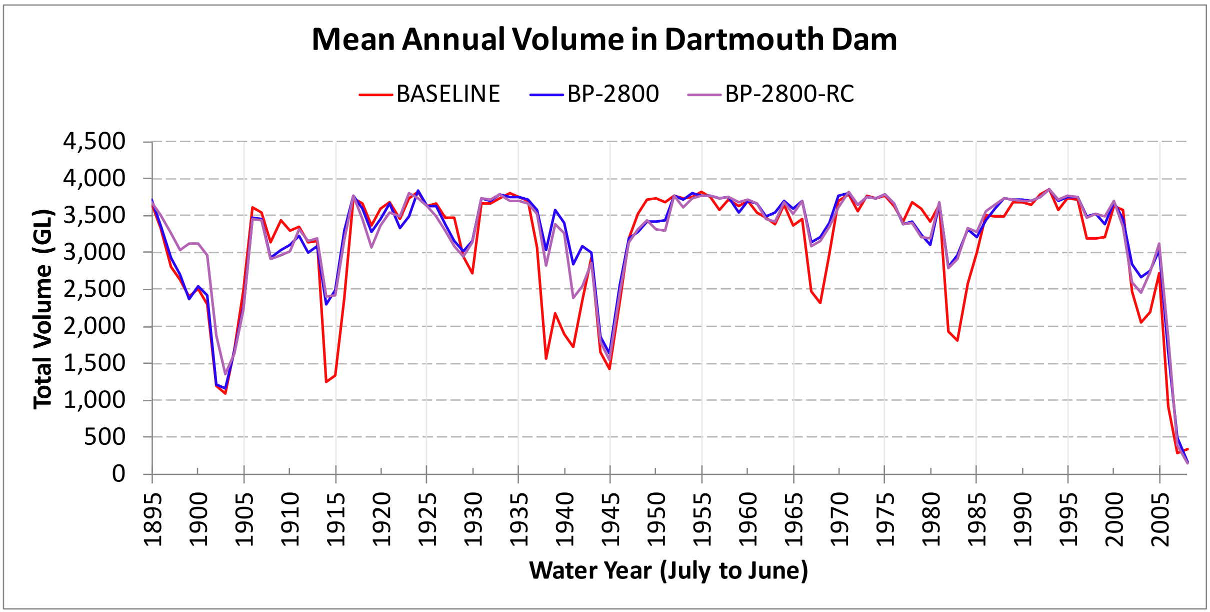
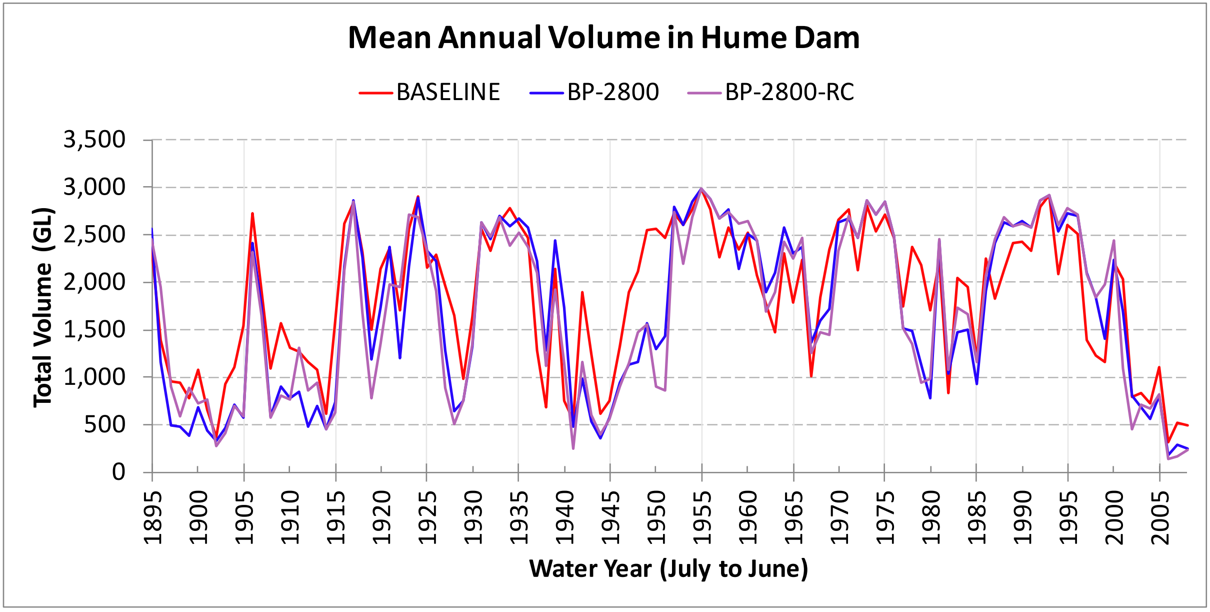
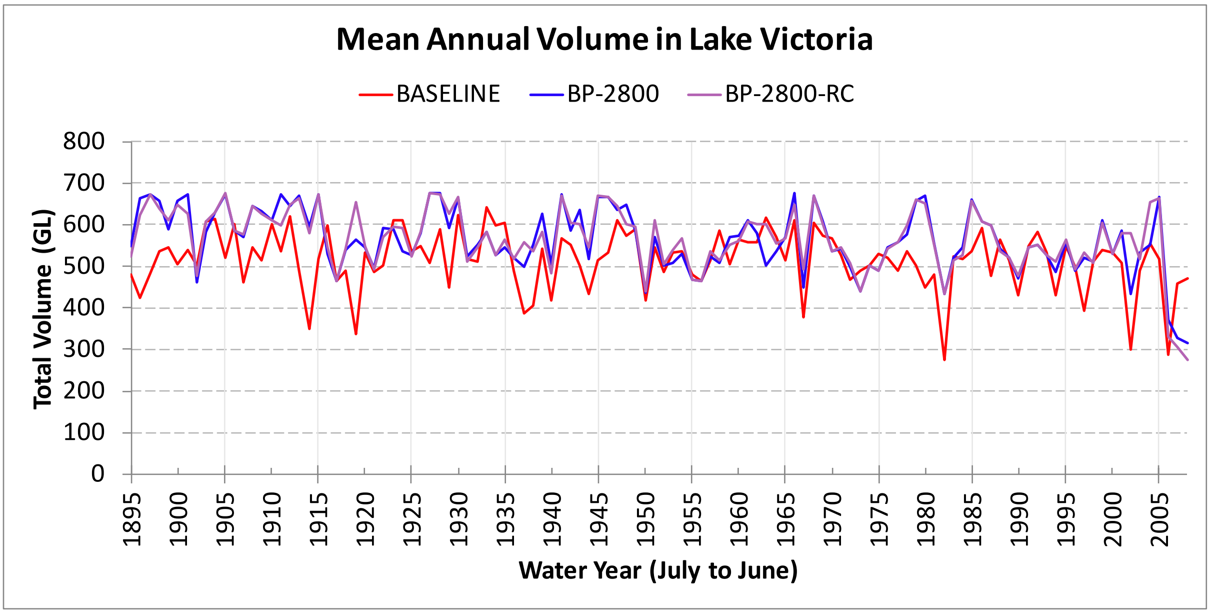

Annual Lower Darling Murray Diversions
BASELINE
BP-2800
BP-2800-RC
Diversions (GL/y)
0
10
20
30
40
50
60
70
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

Figure 11: Average annual volume in the four main storages in the River Murray System (Dartmouth, Hume, Lake Victoria and Menindee Lakes) for the baseline, BP-2800 and BP-2800-RC scenarios.






Mean Annual Volume in Lake Victoria
BASELINE
BP-2800
BP-2800-RC
Total Volume (GL)
800
700
600
500
400
300
200
100
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

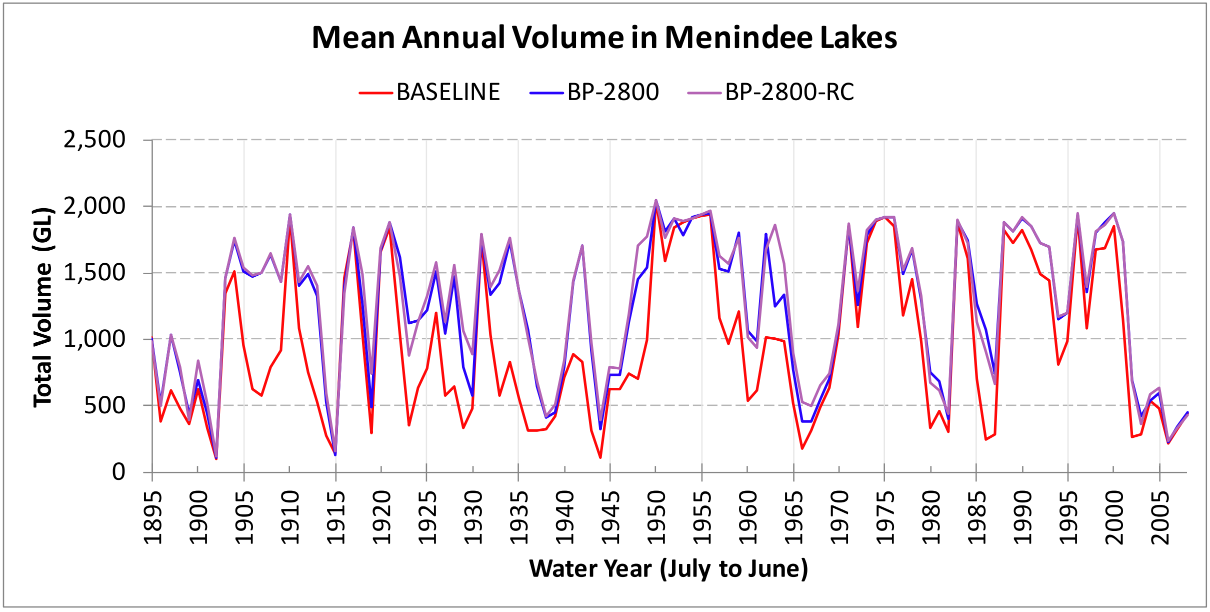
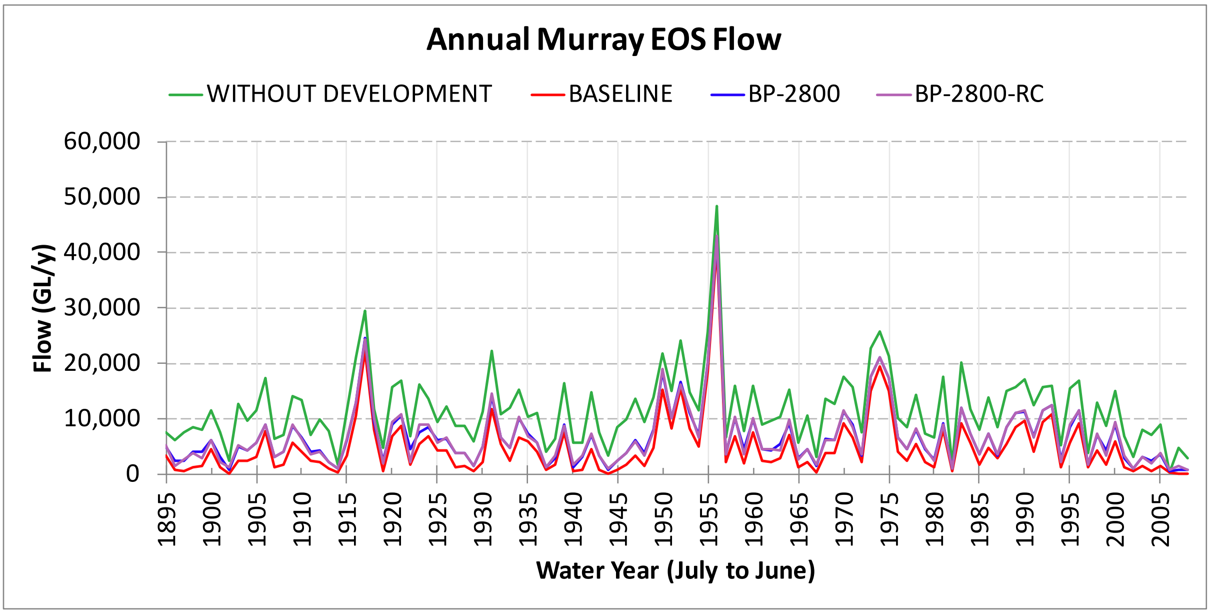

Mean Annual Volume in Menindee Lakes
BASELINE
BP-2800
BP-2800-RC
Total Volume (GL)
2,500
2,000
1,500
1,000
500
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

Figure 12: Annual flows at the end of the River Murray System (barrages) for the without development, baseline, BP-2800 and BP-2800-RC scenarios.

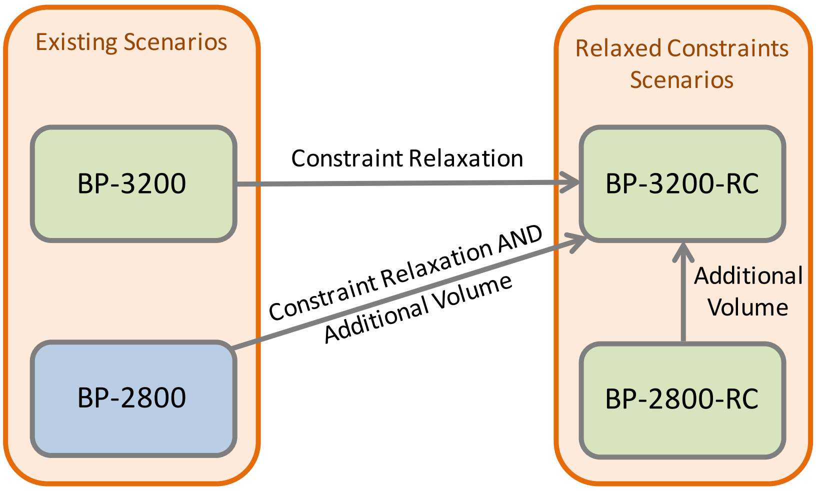


5.2 Results – BP-3200-RC

5.2.1 Environmental results

The BP-3200-RC results in this chapter are discussed in comparison to the three related scenarios (BP-2800, BP-2800-RC and BP-3200). As shown in Figure 13, each comparison can be used to explore the consequences of a specific action. For instance, a comparison to the BP-3200 scenario indicates the potential environmental benefits of relaxing constraints, while a comparison with the BP-2800-RC scenario explores the impacts of increasing the volume of water recovered for the environment by 400 GL/y. Finally, a comparison to the BP-2800 scenario indicates the potential benefits of combining the relaxation of constraints with 400 GL/y of additional water for the environment. Each of these comparisons is made in the subsections below for the indicator sites on the River Murray.

Figure 13: Schematic diagram outlining the scenario comparisons described in the results section for each River Murray hydrological indicator site.



A full description of the analysis techniques used here can be found in the Hydrologic Modelling Report (MDBA 2012b). The main criterion used to measure the level to which the targets for each indicator have been met is the event frequency (that is, the number of successful events over the 114-year modelling period). As in MDBA (2012b) events ordered and delivered within 10% are considered successful, on the basis that the water required to reinstate the flow indicator event is in the environmental water account and it is likely these events could be fully delivered with further optimisation of environmental water delivery in the model or with improved environmental flow delivery in practice.

The analysis presented in this section is focused on the long-term average event frequencies for each flow indicator; however, some consideration has also been given to the duration of dry spells between these events. Consistent with the Hydrologic Modelling Report (MDBA 2012b), this includes a list of the maximum dry spell for each hydrologic indicator in the Murray and Lower Darling system (Table 13 and Table 14), and some discussion regarding changes between the original BP scenarios and the relaxed constraints scenarios. An analysis of other aspects of these changes to the dry spell durations is included in Section 5.3.

Table 12: Proportion of years containing a successful environmental event for the key hydrologic indicator sites on the River Murray.

Hydrologic Indicator site	Flow indicator	Target: high to low uncertainty	Without develop-ment	Baseline	BP-2800[1]	BP-2800-RC[1]	BP-3200[1]	BP-3200-RC[1]
Barmah–Millewa Forest	12,500 ML/d for 70 days	70 - 80%	87%	50%	83%	82%	83%	82%
	16,000 ML/d for 98 days	40 - 50%	66%	30%	58%	52%	61%	55%
	25,000 ML/d for 42 days	40 - 50%	66%	30%	44%	46%	47%	46%
	35,000 ML/d for 30 days	33 - 40%	53%	24%	30%	33%	31%	35%
	50,000 ML/d for 21 days	25 - 30%	39%	18%	16%	14%	18%	16%
	60,000 ML/d for 14 days	25 - 30%	33%	14%	11%	11%	11%	10%
	15,000 ML/d for 150 days	30%	44%	11%	38%	39%	36%	39%
Gunbower–Koondrook–Perricoota Forest	16,000 ML/d for 90 days	70 - 80%	86%	31%	68%	67%	71%	71%
	20,000 ML/d for 60 days	60 - 70%	87%	34%	60%	59%	61%	61%
	30,000 ML/d for 60 days	33 - 50%	60%	25%	38%	36%	39%	38%
	40,000 ML/d for 60 days	25 - 33%	39%	11%	18%	20%	24%	25%
	20,000 ML/d for 150 days	30%	43%	7%	27%	25%	29%	32%
Hattah Lakes	40,000 ML/d for 60 days	40 - 50%	67%	30%	46%	45%	50%	46%
	50,000 ML/d for 60 days	30 - 40%	47%	19%	32%	32%	33%	35%
	70,000 ML/d for 42 days	20 - 33%	38%	11%	18%	17%	21%	20%
	85,000 ML/d for 30 days	20 - 30%	33%	10%	13%	13%	14%	15%
	120,000 ML/d for 14 days	14 - 20%	23%	8%	8%	8%	8%	8%
	150,000 ML/d for 7 days	10 - 13%	17%	5%	5%	5%	6%	6%
Riverland–Chowilla Floodplain	20,000 ML/d for 60 days	72 - 80%	89%	43%	72%	68%	75%	74%
	40,000 ML/d for 30 days	50 - 70%	80%	37%	61%	58%	61%	57%
	40,000 ML/d for 90 days	33 - 50%	58%	22%	36%	34%	39%	36%
	60,000 ML/d for 60 days	25 - 33%	41%	12%	25%	25%	27%	25%
	80,000 ML/d for 30 days	17 - 25%	34%	10%	14%[2]	13%	14%	18%
	100,000 ML/d for 21 days	13 - 17%	19%	6%	5%	6%	7%	6%
	125,000 ML/d for 7 days	10 - 13%	17%	4%	4%	4%	4%	4%

🟩 Low uncertainty frequency or better
🟩 Low uncertainty to high uncertainty frequency range
🟨 Below high uncertainty frequency; improvement relative to baseline
⬜ No environmental demands specified in model - Demands not included in previous MDBA modelling that informed ESLT. The majority of these are considered beyond capacity for managed delivery and therefore not part of 'actively managed' floodplain

[1] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

[2] This number was erroneously reported as 13% in the Hydrologic Modelling Report (MDBA 2012b).

Table 13: Overview of maximum dry periods between flow indicator events for hydrologic indicator sites on the River Murray system.

Hydrologic Indicator site	Flow indicator	Maximum dry period in years between successful flow indicator events						Maximum dry period in years between successful flow indicator events (includes events within 10%)*			
		Without dev'ment	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC	BP-2800*	BP-2800-RC*	BP-3200*	BP-3200-RC*
Barmah–Millewa Forest	12,500 ML/d for 70 days (Jun-Nov)	4	7	4	4	4	4	4	4	4	4
	16,000 ML/d for 98 days (Jun-Nov)	4	13	7	5	4	5	7	5	4	5
	25,000 ML/d for 42 days (Jun-Nov)	5	12	10	8	10	8	9	8	10	8
	35,000 ML/d for 30 days (Jun-May)	5	12	16	9	10	13	16	9	10	13
	50,000 ML/d for 21 days (Jun-May)	11	22	22	22	22	22	22	22	22	22
	60,000 ML/d for 14 days (Jun-May)	11	22	24	24	24	24	24	24	24	24
	15,000 ML/d for 150 days (Jun-Dec)	6	21	6	6	6	6	6	6	6	6
Gunbower–Koondrook–Perricoota Forest	16,000 ML/d for 90 days (Jun-Nov)	4	13	9	9	4	9	4	4	4	4
	20,000 ML/d for 60 days (Jun-Nov)	4	13	9	9	4	9	6	6	4	6
	30,000 ML/d for 60 days (Jun-May)	5	13	13	13	13	13	13	13	13	13
	40,000 ML/d for 60 days (Jun-May)	9	22	21	17	21	13	17	16	13	13
	20,000 ML/d for 150 days (Jun-Dec)	9	35	21	21	14	14	14	14	13	11
Hattah Lakes	40,000 ML/d for 60 days (Jun-Dec)	4	13	13	9	9	9	9	9	5	9
	50,000 ML/d for 60 days (Jun-Dec)	6	13	13	13	13	13	13	13	13	13
	70,000 ML/d for 42 days (Jun-Dec)	9	22	21	21	21	21	13	21	13	21
	85,000 ML/d for 30 days (anytime)	11	22	22	22	22	22	22	22	22	22
	120,000 ML/d for 14 days (anytime)	13	24	24	24	24	24	24	24	24	24
	150,000 ML/d for 7 days (anytime)	14	38	38	38	24	38	38	38	24	38
Riverland–Chowilla Floodplain	20,000 ML/d for 60 days (Aug-Dec)	4	11	4	4	4	4	4	4	4	4
	40,000 ML/d for 30 days (Jun-Dec)	4	13	9	9	9	9	6	6	6	6
	40,000 ML/d for 90 days (Jun-Dec)	5	13	13	13	13	13	13	13	9	13
	60,000 ML/d for 60 days (Jun-Dec)	9	22	22	21	21	21	14	14	13	14
	80,000 ML/d for 30 days (anytime)	11	22	22	22	22	22	22	22	22	22
	100,000 ML/d for 21 days (anytime)	13	24	38	24	24	25	38	24	24	25
	125,000 ML/d for 7 days (anytime)	13	38	38	38	38	39	38	38	38	39

*Includes events that were ordered in the demand timeseries and were achieved within 10% of the flow indicator threshold and duration (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Table 14: Overview of maximum dry periods between flow indicator events for Edward–Wakool and Lower Darling Floodplain hydrologic indicator sites.

Hydrologic Indicator site	Flow indicator	Maximum dry period in years between successful flow indicator events					
		Without develop-ment	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Edward Wakool River System	1,500 ML/d for 180 days (Jun-Mar)	4	3	3	3	3	3
	5,000 ML/d for 60 days (Jun-Dec)	4	11	4	5	4	5
	5,000 ML/d for 120 days (Jun-Dec)	5	13	11	11	11	11
	18,000 ML/d for 28 days (Jun-Dec)	11	22	22	22	22	22
	30,000 ML/d for 21 days (Jun-Dec)	11	35	24	24	24	24
Lower Darling Floodplain	20,000 ML/d for 30 days (Jan-Dec)	15	29	29	29	29	29
	25,000 ML/d for 45 days (Jan-Dec)	29	29	29	29	29	29
	45,000 ML/d for 2 days (Jan-Dec)	29	29	29	29	29	29
	7,000 ML/d for 10 days (Jan-Dec)	2	8	7	8	7	8
	17,000 ML/d for 18 days (Jan-Dec)	8	29	28	29	28	29

Barmah–Millewa Forest

Changes to the modelled environmental demands

The BP-2800-RC environmental demand series at this site was slightly modified for the BP-3200-RC scenario to include demands for an additional four events associated with the seventh indicator (15,000 ML/d for 150 days). This indicator is associated with conditions conducive for bird breeding and the events were added to match bird breeding events further down the system at Gunbower–Koondrook–Perricoota Forest.

Consistent with the altered environmental water delivery strategy described in Section 3, the number of low- to mid-flow events in the relaxed constraints sequence is less than was included in the BP-3200 sequence. Overall, eleven 16,000 ML/d events and five 25,000 ML/d events were removed, and this volume was partly made available in the model to the higher flow 35,000 ML/d indicator.

A summary of the resultant changes to the achievement of the flow indicators is at Box 2 and further description and analysis follows.

Box 2: Summary of results for Barmah–Millewa Forest

Summary of BP-3200-RC Results: Barmah–Millewa Forest

The most significant change in the flow regime at this site was associated with mid- to high-flow events of 35,000 ML/d (duration 30 days). Flows of this magnitude inundate large areas of flood-dependent river red gum forest and river red gum/box woodland, and the modelling results indicate that relaxing flow constraints downstream of Hume Dam would improve environmental outcomes.

The relaxation of constraints from the BP-3200 scenario has:

- increased the frequency of 35,000 ML/d events, satisfying the target
- decreased the frequency of unregulated high-flow (50,000 and 60,000 ML/d) events owing to changes in dam spill patterns.

The addition of 400 GL of available environmental water from the BP-2800-RC scenario has:

- increased the frequency of 35,000 ML/d events.

The combination of additional water and relaxed constraints from the BP-2800 has:

- increased the frequency of 35,000 ML/d events, satisfying the target
- improved the maximum dry period results for 16,000, 25,000 and 35,000 ML/d events.

Table 15: Flow indicator achievement for the Barmah–Millewa Forest under without development, baseline, BP-3200 and BP-3200-RC conditions.

			Without development	Baseline	BP-3200*		BP-3200-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the River Murray at Yarrawonga Weir)		Target proportion of years with a successful event – high to low uncertainty						
1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	87%	50%	95	83%	93	82%
2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	69	61%	63	55%
3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	54	47%	53	46%
4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33 - 40 %	53%	24%	35	31%	40	35%
5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25 - 30 %	39%	18%	21	18%	18	16%
6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20 - 25 %	33%	14%	13	11%	11	10%
7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	44%	11%	41	36%	45	39%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Impacts of constraint relaxation: BP-3200 to BP-3200-RC

The most significant change between the two 3200 GL/y scenarios is associated with the 35,000 ML/d indicator (Table 15). The target frequency for this indicator was not satisfied in the BP-3200 scenario (Table 88; MDBA 2012b) but was met because of the relaxation of constraints and the associated change in the environmental water delivery strategy. This changed strategy (in which water has been reallocated from the lower component of the flow regime and redistributed in the model to the mid- to high-component) also produced a reduction in the event frequency for the second indicator (16,000 ML/d for 98 days), although the target frequency range was still satisfied.

The event frequencies for the fifth and sixth indicators (50,000 ML/d for 21 days; 60,000 ML/d for 14 days) decreased in the relaxed constraints scenario. These events are considered to be beyond regulated delivery capacity, and they therefore rely on spills from Hume Dam and/or unregulated high-flow events from upstream tributaries. Therefore, there were no environmental demands for these events. The frequency of these events fell because of the changed characteristics of spills from Hume Dam, which is the result of increased releases due to the relaxation of constraints. This is an artefact of the combination of environmental demands (active use of a bigger environmental water portfolio calling water earlier in the year), rather than the relaxation of constraints per se.

Impacts of Additional Volume: BP-2800-RC to BP-3200-RC

A comparison between the BP-2800-RC results (Table 3) and the BP-3200-RC results (Table 15) indicates only minor changes at this site as a result of the additional recovered volume—the differences between event frequencies for each indicator are at most 2% (i.e. two events over the 114 years). As described in Section 5.1, the target frequency for the fourth indicator (associated with flows of 35,000 ML/d) was achieved in the BP-2800-RC scenario, an improvement from the original BP-2800 scenario. This result has further improved in the BP-3200-RC scenario, with an additional two events over the 114-year modelling period, suggesting that an increased volume of water for the environment provides a higher confidence of meeting this flow requirement.

Combined Impacts of Additional Volume and Constraint Relaxation: BP-2800 to BP-3200-RC

The combination of constraint relaxation and the availability of additional environmental water had a significant effect on the flow indicator results for the Barmah–Millewa Forest (Table 86; MDBA 2012b). An additional six events associated with the 35,000 ML/d indicator over the 114-year period met the desired frequency and reduced the maximum period between events (from 16 to 13 years). The number of 16,000 ML/d and 25,000 ML/d events decreased as a direct result of the altered environmental watering strategy; however, these still satisfied the target event frequency. Furthermore, the maximum period between events decreased for both indicators (from seven to five years, and ten to eight years respectively).

In relation to the two high-flow indicators, the number of events associated with the 50,000 ML/d indicator has remained the same, while the 60,000 ML/d indicator has decreased by two events. The change in the 60,000 ML/d indicator is due to the changed nature of spills from Hume Dam in the relaxed constraints scenario. This is an artefact of the environmental demands, rather than the relaxation of constraints per se, and could be overcome in the modelling (and in practice) with a slightly different set of environmental flow events.

Gunbower–Koondrook–Perricoota Forest

Changes to the modelled environmental demands

The addition of 400 GL/y of available environmental water allowed an increased number of environmental events to be ordered to this site (compared to the BP-2800-RC scenario). Additional events were selected for all flow indicators, and a summary of these changes can be found in Table 2.

A summary of the resultant changes to the achievement of the flow indicators is at Box 3 and further description and analysis follows.

Box 3: Summary of results for Gunbower–Koondrook–Perricoota Forest

Summary of BP-3200-RC results: Gunbower–Koondrook-Perricoota Forest

The indicator results at this site suggest that the relaxation of flow constraints improves the ability to deliver high flow events—the target frequency has been satisfied for the 40,000 ML/d indicator. Furthermore, the target frequency for the indicator associated with conditions conducive for bird-breeding (20,000 ML/d for 150 days) has also been satisfied. Both of these achievements are an improvement on all three comparison scenarios, and the indicator results also show associated improvements in the maximum period between events.

The <u>relaxation of constraints</u> from the BP-3200 scenario has:

- increased the frequency of the following events, satisfying the targets:
    - 40,000 ML/d for 60 days
    - 20,000 ML/d for 150 days
- reduced the maximum dry period associated with the 40,000 ML/d indicator (from 21 to 13 years).

The <u>addition of 400 GL of available environmental water</u> from the BP-2800-RC scenario has:

- increased the frequency of the following events, satisfying the targets:
    - 16,000 ML/d for 90 days
    - 20,000 ML/d for 60 days
    - 40,000 ML/d for 60 days
    - 20,000 ML/d for 150 days
- reduced the maximum dry period associated with the 40,000 ML/d and 20,000 ML/d (150 day) indicators.

The <u>combination of additional water and relaxed constraints</u> from the BP-2800 has:

- increased the frequency of the following events, satisfying the targets
    - 16,000 ML/d for 90 days
    - 40,000 ML/d for 60 days
    - 20,000 ML/d for 150 days
- reduced the maximum dry period associated with the 40,000 ML/d and 20,000 ML/d (150 day) indicators.

Table 16: Flow indicator achievement for the Gunbower–Koondrook–Perricoota Forest under without development, baseline, BP-3200 and BP-3200-RC conditions.

			Without development	Baseline	BP-3200[*]		BP-3200-RC[*]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
	Flow Event - threshold, duration, season (as gauged on the River Murray at Torrumbarry Weir)	Target proportion of years with a successful event - high to low uncertainty						
1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	86%	31%	81	71%	81	71%
2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60 - 70 %	87%	34%	70	61%	69	61%
3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33 - 50 %	60%	25%	44	39%	43	38%
4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25 - 33 %	39%	11%	27	24%	28	25%
5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	43%	7%	33	29%	37	32%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Impacts of constraint relaxation: BP-3200 to BP-3200-RC

The relaxation of constraints improved the indicator results for the high-flow events (40,000 ML/d; Table 16). This is consistent with the results at other sites along the River Murray, which suggest that constraint relaxation has the greatest impact on the delivery of events located in the higher component of the flow regime.

The results also suggest that, in addition to the improved frequency of 40,000 ML/d events, the relaxation of flow constraints would allow the peak and duration of existing events to be enhanced. The environmental outcomes in the Gunbower–Koondrook–Perricoota Forest are strongly associated with the duration of the flooding event; hence the relaxation of constraints would be expected to result in improved outcomes for existing events.

The relaxation of constraints also improved the indicator results for the 20,000 ML/d (for 150 days) flow events, which are associated with flows conducive for bird breeding.

Impacts of additional volume: BP-2800-RC to BP-3200-RC

The availability of 400 GL/y of additional environmental water in the southern connected system had a substantial positive impact on the flow indicator results (Table 16). Four of the five indicator results did not meet the target frequencies in the BP-2800-RC scenario; but all were achieved in the BP-3200-RC scenario. There was also an associated improvement in the maximum period between events for the 40,000 ML/d indicator (decreasing from 17 to 13 years) and the 150-day 20,000 ML/d indicator (from 21 to 14 years).

Combined impacts of additional volume and constraint relaxation: BP-2800 to BP-3200-RC

Three of the five target indicator frequencies at this site were not achieved in the BP-2800 scenario; but these were all satisfied in the BP-3200-RC scenario (Table 16), with an associated improvement in maximum dry period results for three of these indicators (Table 13). Similar to the 'BP-3200 to BP-3200-RC' comparison above, the results also indicated an improvement in the peak flow and duration of events common to both scenarios. These results support the conclusion that the combination of constraint relaxation and additional recovered volume for the environment would enhance the ability to achieve the desired environmental outcomes at this site.

Hattah Lakes

Changes to the modelled environmental demands

Consistent with the environmental watering strategy described in Section 3, the increased volume of available environmental water was ordered predominately towards the higher component of the flow regime at this site. The number of low- to mid-flow events (40,000 and 50,000 ML/d) included in the demand series at this site was unchanged from the BP-2800-RC scenario, and the number of 70,000 and 85,000 ML/d events was increased by six and seven respectively (Table 2). In addition, the relaxation of constraints allowed a larger volume to be delivered to each high-flow event than was possible in the original BP-3200 scenario.

A summary of the resultant changes to the achievement of the flow indicators is at Box 4 and further description and analysis follows.

Box 4: Summary of results for Hattah Lakes

Summary of BP-3200-RC Results: Hattah Lakes

The relaxation of constraints allowed an improvement to the peak and duration of delivered environmental events in the BP-3200-RC scenario; however these changes have not been strong enough at this site to register as a change to the flow indicator results. The indicator results at this indicator site show a greater response to increased availability of environmental water than to relaxation of constraints. The target for the 70,000 ML/d indicator is achieved in both BP-3200 scenarios, but not in the two BP-2800 scenarios, while the other high-flow indicator (85,000 ML/d for 30 days) shows some improvement under both BP-3200 scenarios.

The relaxation of constraints from the BP-3200 scenario has:

- increased the frequency of 50,000 ML/d events.

The addition of 400 GL of available environmental water from the BP-2800-RC scenario has:

- increased the frequency of 70,000 ML/d events, satisfying the target
- increased the frequency of the following events:
    - 50,000 ML/d for 60 days
    - 85,000 ML/d for 30 days.

The combination of additional water and relaxed constraints from the BP-2800 has:

- Increased the frequency of 70,000 ML/d events, satisfying the target
- increased the frequency of the following events:
    - 50,000 ML/d for 60 days
    - 85,000 ML/d for 30 days.

Table 17: Flow indicator achievement for Hattah Lakes under without development, baseline, BP-3200 and BP-3200-RC conditions.

			Without development	Baseline	BP-3200*		BP-3200-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the River Murray at Euston Weir)		Target proportion of years with a successful event - high to low uncertainty						
1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40 - 50 %	67%	30%	57	50%	52	46%
2	50,000 ML/d for a total duration of 60 days (with a min duration of 7 consecutive days) between Jun & Dec	30 - 40 %	47%	19%	38	33%	40	35%
3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20 - 33 %	38%	11%	24	21%	23	20%
4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20 - 30 %	33%	10%	16	14%	17	15%
5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14 - 20 %	23%	8%	9	8%	9	8%
6	150,000 ML/Day for 7 consecutive days between Jun & May	10 - 13 %	17%	5%	7	6%	7	6%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

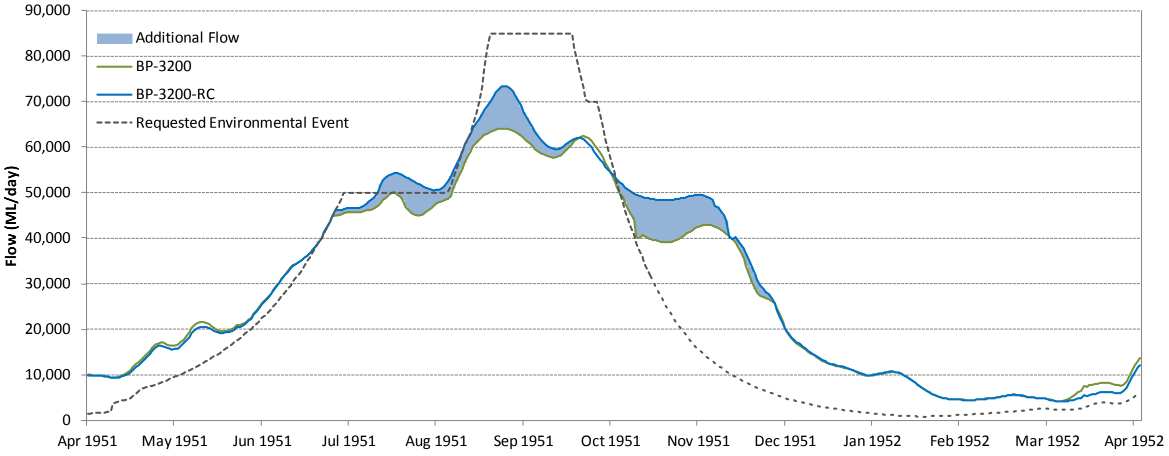
Impacts of constraint relaxation: BP-3200 to BP-3200-RC

Similar to the BP-2800-RC results discussed above, the relaxation of constraints produced little change in the Hattah Lakes flow indicator results (Table 17). The frequency of 40,000 ML/d events decreased by 4% as a result of altered environmental watering strategy, while the other three indicators (for which environmental demands were specified) changed by 2% or less.

As was noted in the discussion of the BP-2800-RC scenario above, the relatively small changes to the indicator results emphasises the relative coarseness of the environmental flow indicators, which do not always detect ecologically significant changes in the flow regime. The modelling results indicated that the additional water delivered in the higher section of the flow regime supplemented events already present in the BP-3200 scenario, rather than added new events at this site, which does suggest subtle but nonetheless important changes to the flow regime.

An example of a requested 70,000 ML/d event downstream of Euston is displayed in Figure 14. In total, the relaxation of constraints allowed the delivery of an additional 660 GL to this site, significantly increasing the peak and duration of the flood event. The peak flow increased from 64,000 to 73,000 ML/d, inundating approximately 5,000 ha of additional floodplain from Euston to Lock 10.The duration of the 50,000 ML/d event increased from 59 to 91 days. This was not registered as a successful event in either scenario; however, the increased peak and duration of the inundation event due to constraint relaxation would have environmental benefits to the flood-dependent vegetation in this reach.

Figure 14: An example of changes to the delivery of requested 50,000, 70,000 and 85,000 ML/d events for the Hattah Lakes indicator site (flows measured downstream of Euston Weir) in 1951, due to modelled constraint relaxation.



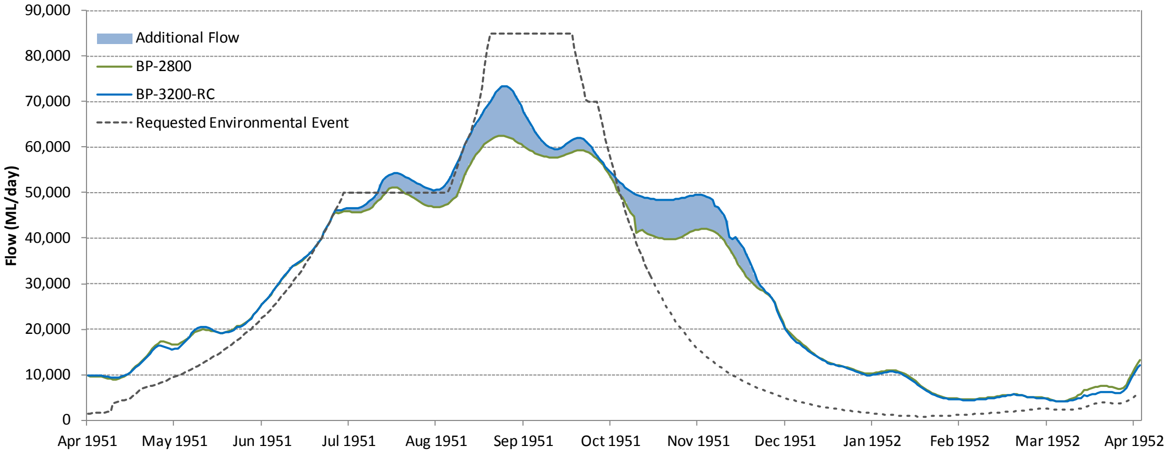
Impacts of additional volume: BP-2800-RC to BP-3200-RC

The additional 400 GL/y of water for the environment provided a further four successful 70,000 ML/d events over the 114-year modelling period, meeting the target frequency (Table 17). Furthermore, the number of 50,000 and 85,000 ML/d events increased (by four and two respectively). However these improvements did not change the overall indicator result. There was also no change to the maximum dry period for each indicator (Table 13).

Combined impacts of additional volume and constraint relaxation: BP-2800 to BP-3200-RC

As measured by the flow indicators, the differences between the BP-2800 and BP-3200-RC scenarios are similar to those for the BP-2800-RC to BP-3200-RC comparison described above. That is, the frequency of 70,000 ML/d events satisfied the target, and the frequency of 40,000 and 85,000 ML/d events increased, but with no change to the success of the indicators.

Figure 15 An example hydrograph showing the effects of requested 50,000, 70,000, and 85,000 ML/d events for the Hattah Lakes indicator site (flows measured downstream of Euston Weir) in 1951.



However, the same arguments as were used in the BP-3200 to BP-3200-RC comparison above are applicable here—the frequencies for many indicators did not change, yet the relaxation of constraints allowed the flow enhancement of some events. For comparison, the example hydrograph in Figure 14 is repeated in Figure 15, but instead compared to the BP-2800 scenario. The results are similar, in that constraint relaxation allowed an additional 730 GL of water to be delivered at this site, improving the peak and duration of this environmental watering event.

Riverland–Chowilla Floodplain

Changes to the modelled environmental demands

The increased volume of environmental water allowed the number of events in the demand series for Chowilla to be increased compared to the BP-2800-RC sequence. Consistent with the environmental water delivery strategy outlined in Section 3, these additional events targeted the higher end of the regulated flow regime. Four 60,000 ML/d events and four 80,000 ML/d events were added to the demand series for the BP-3200-RC scenario.

A summary of the resultant changes to the achievement of the flow indicators is at Box 5 and further description and analysis follows.

Box 5: Summary of results for Chowilla Floodplain

Summary of BP-3200-RC results: Riverland-Chowilla Floodplain

The *achievement of the 80,000 ML/d (30-day duration) indicator target* for this scenario emphasises the significant improvement at the high end of the regulated flow regime for this indicator site and the River Murray floodplain downstream of the Darling junction.

Flows of this magnitude inundate large areas of flood-dependent lignum, river red gum forest and river red gum/box woodland, and the modelling results indicate that the combination of flow constraint relaxation and additional environmental water would greatly improve the ability to deliver these events.

The relaxation of constraints from the BP-3200 scenario has:

- increased the frequency of 80,000 ML/d events, satisfying the target
- increased the frequency of fully successful 60,000 ML/d events.

The addition of 400 GL of available environmental water from the BP-2800-RC scenario has:

- Increased the frequency of 80,000 ML/d events, satisfying the target
- increased the frequency of 20,000 ML/d events, satisfying the target.

The combination of additional water and relaxed constraints from the BP-2800 has:

- Increased the frequency of 80,000 ML/d events, satisfying the target
- increased the frequency of fully successful 60,000 ML/d events.

The most significant difference between the BP-3200-RC scenario and the three comparison scenarios was in the number of 80,000 ML/d events assessed as successful (Table 18). These events are considered to be at the limit of regulated deliverability (because of their high threshold and 30-day duration), and are important for maintaining the water-dependent ecosystem on the fringing floodplain, both at this site and throughout the wider reach. The frequency of events was relatively constant for the three comparison scenarios (13% or 14%), and did not satisfy the target frequency of 17%. However, the target frequency is met in the BP-3200-RC scenario (18%), indicating that the combination of relaxed constraints and additional water for the environment can have significant impacts in this component of the flow regime.

Table 18: Flow indicator achievement for the Riverland–Chowilla Floodplain under without development, baseline, BP-3200 and BP-3200-RC conditions.

			Without development	Baseline	BP-3200*		BP-3200-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
	Flow Event - threshold, duration, season (as gauged on the River Murray at SA Border)	Target proportion of years with a successful event - high to low uncertainty						
1	20,000 ML/d for 60 consecutive days between Aug & Dec	72 - 80 %	89%	43%	85	75%	84	74%
2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50 - 70 %	80%	37%	69	61%	65	57%
3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33 - 50 %	58%	22%	44	39%	41	36%
4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25 - 33 %	41%	12%	31	27%	29	25%
5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17 - 25 %	34%	10%	16	14%	20	18%
6	100,000 ML/d for a total duration of 21 days between Jun & May	13 - 17 %	19%	6%	8	7%	7	6%
7	125,000 ML/d for a total duration of 7 days between Jun & May	10 - 13 %	17%	4%	5	4%	4	4%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

Impacts of constraint relaxation: BP-3200 to BP-3200-RC

Beyond the achievement of the 80,000 ML/d target, there was little change to the flow indicator results between the BP-3200 and BP-3200-RC scenarios. Consistent with the altered environmental water delivery strategy, the number of low- to mid-flow events (thresholds of 40,000 to 60,000 ML/d) has decreased (Table 18); however, these are still satisfying the target frequencies. Furthermore, the duration of the maximum dry periods for each indicator has not changed substantially between the two scenarios (Table 13).

A closer examination of Table C.8 (Appendix C) and Table 97 in the Hydrological Modelling Report (MDBA 2012b) indicates that three of the 'delivered within 10%' events for the 60,000 ML/d flow indicator are now fully delivered as a result of the constraint relaxation. This does not change the achieved frequency; however, it does indicate that there would be a greater confidence to produce the desired environmental outcomes under a relaxed constraints regime.

Impacts of additional volume: BP-2800-RC to BP-3200-RC

The flow indicator results at Chowilla changed as a result of the additional water for the environment. As described above, the four additional 80,000 ML/d events over the 114-year period have meant the target frequency for this indicator has been met. Furthermore, the target frequency for the Chowilla freshes indicator (20,000 ML/d for 60 days) has been satisfied; however, this is an indirect result of other environmental watering actions (at this site and other sites in the southern connected system) as no environmental demands were specified in the model to directly target these events. There has been no substantial change to the length of maximum dry periods for all flow indicators (Table 13).

Combined impacts of additional volume and constraint relaxation: BP-2800 to BP-3200-RC

A comparison to the BP-2800 scenario indicates significant benefits can be achieved at the higher end of the regulated flow regime by combining the effects of constraints relaxation and additional water for the environment, embodied in the achievement of the 80,000 ML/d indicator target frequency. Furthermore, two of the successful (within 10%) 60,000 ML/d events in the BP-2800 were fully successful in the BP-3200-RC scenario, again indicating that the relaxation of constraints would increase the confidence of satisfying the environmental requirements associated with this component of the flow regime (Table C.8 in Appendix C, compared with Table 95 in the Hydrological Modelling Report).

The number of 40,000 ML/d (30 day duration) events decreased as a result of changes in the environmental watering strategy, yet the target is still satisfied and the maximum dry period has not increased (Table 13). There has been no substantial change to the flow indicator results in the unregulated component of the flow regime (i.e. flows of 100,000 ML/d and 125,000 ML/d), noting nevertheless that the number of 100,000 ML/d events increased from six to seven and the maximum dry period between these events decreased from 38 to 25 years.

Lower Darling and Edward-Wakool River systems

Consistent with the methodology applied in the BP-2800 and BP-3200 scenarios, demand series were not developed for these two indicator sites, thus any changes in environmental indicator results here would be an indirect consequence of changes to watering actions at upstream of downstream sites, and therefore not able to be directly attributed to the relaxation of constraints. Overall, the results (Table 19 and Table 20) demonstrate only minor changes compared to the BP-2800, BP-2800-RC and BP-3200 scenarios.

The most significant change was found for the lowest threshold indicator (7,000 ML/d) for the Lower Darling system, which has decreased from 60% (BP-3200) to 56% (BP-3200-RC). This is an unintended effect of the constraint relaxation process to allow larger flows through the Lower Darling system for downstream purposes. The spill and release characteristics of Menindee Lakes have therefore changed, resulting in fewer of these low-threshold flow events. However, these events could be better targeted in the model through an environmental demand series, hence these results likely underestimate the potential benefits to the Lower Darling system that could be achieved under the Basin Plan.

A full description of the potential to meet the Lower Darling and Edward-Wakool River system targets in practice is given the Hydrological Modelling report (MDBA 2012b).

Table 19: Flow indicator achievement for the Edward-Wakool River System under without development, baseline, BP-3200 and BP-3200-RC conditions.

			Without development	Baseline	BP-3200[*]		BP-3200-RC[*]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Edward River at Deniliquin)		Target proportion of years with a successful event - high to low uncertainty						
1	1,500 ML/Day for a total duration of 180 days (with a minimum duration of 1 consecutive day) between Jun & Mar	99 - 100 %	75%	96%	107	94%	106	93%
2	5,000 ML/Day for a total duration of 60 days (with a minimum duration of 7 consecutive days) between Jun & Dec	60 - 70 %	82%	39%	73	64%	71	62%
3	5,000 ML/Day for a total of 120 days (with a minimum duration of 7 consecutive days) between Jun & Dec	35 - 40 %	52%	22%	41	36%	44	39%
4	18,000 ML/Day for a total of 28 days (with a minimum duration of 5 consecutive days) between Jun & Dec	25 - 30 %	39%	15%	20	18%	18	16%
5	30,000 ML/Day for a total of 21 days (with a minimum duration of 6 consecutive days) between Jun & Dec	17 - 20 %	28%	12%	12	11%	11	10%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Table 20: Flow indicator achievement for the Lower Darling Floodplain under without development, baseline, BP-3200 and BP-3200-RC conditions.

			Without development	Baseline	BP-3200[*]		BP-3200-RC[*]	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Darling River at Weir 32)		Target proportion of years with a successful event - high to low uncertainty						
1	20,000 ML/Day for 30 consecutive days between Jun & May	14 - 20 %	27%	10%	13	11%	13	11%
2	25,000 ML/Day for 45 consecutive days between Jun & May	8 - 10 %	14%	8%	9	8%	9	8%
3	45,000 ML/Day for 2 consecutive days between Jun & May	7 - 10 %	11%	8%	9	8%	9	8%
4	7,000 ML/Day for 10 consecutive days between Jun & May	70 - 90 %	95%	51%	68	60%	64	56%
5	17,000 ML/Day for 18 consecutive days between Jun & May	20 - 40 %	49%	18%	27	24%	30	26%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Coorong, Lower Lakes and Murray Mouth

Changes to the environmental demands

Environmental demands for the Lower Murray in-channel baseflows, freshes and the Coorong, Lower Lakes and Murray Mouth (CLLMM) are expressed at the South Australian border and added iteratively as part of the modelling process. These demands were added only where there was water remaining in the environmental water account after other demands for upstream floodplain sites were met. Consequently, these demands do not represent an explicit demand series intended to achieve all of the salinity and flow indicators developed for this hydrologic indicator site (further description is provided in MDBA 2012b). The summary of key results from the BP-3200-RC scenario contained within Box 6 needs to be considered within this context.

Box 6: Summary of results for Coorong, Lower Lakes and Murray Mouth

Summary of BP-3200-RC Results: Coorong, Lower Lakes and Murray Mouth

The relaxation of constraints from the BP-3200 scenario has:

- resulted in relatively small changes to a number of CLLMM indicators, but not in a consistent manner and not sufficient to result in a change to achievement of targets.

The addition of 400 GL of available environmental water from the BP-2800-RC scenario has:

- decreased maximum salinity in the Coorong northern lagoon, satisfying the target
- reduced average and maximum salinities in the Coorong southern lagoon.
- increased the proportion of years where 3-year rolling average barrage flows are greater than 2,000 GL/y
- improved Murray Mouth openness - Murray bed levels decreased and Murray Mouth remained open for longer during drought periods such as Millennium Drought
- increased minimum water levels in the Lower Lakes further minimising acidification risks
- increased salt export, satisfying the target.

The combination of additional water and relaxed constraints from the BP-2800 has:

- limited additional effect on achievement of CLLMM flow and salinity indicators compared to the benefits of additional environmental water recovery alone as represented in the BP-3200 scenario
- indicated that the recovered volume of environmental water is likely to be a more important determinant of outcomes in the Coorong, Lower Lakes and Murray Mouth than addressing constraints.

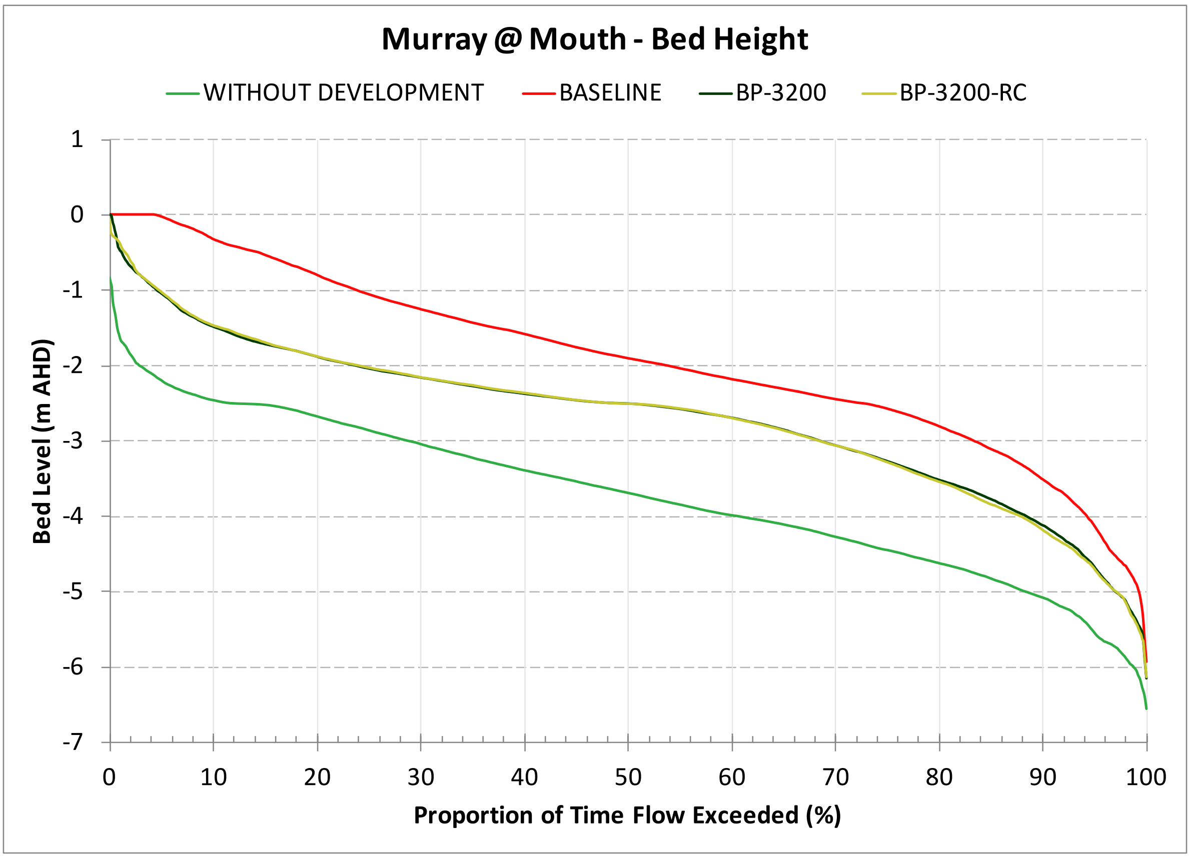
Impacts of constraint relaxation: BP-3200 to BP-3200-RC

Consistent with the results described for the 2800 GL/y scenarios with constraints maintained and relaxed, there are only small and inconsistent differences between the two 3200 GL/y scenarios. While the Coorong northern lagoon maximum salinity improved marginally in the BP-3200-RC scenario from 47 g/L to 43 g/L, other indicators (Coorong southern lagoon maximum salinity and 3-year rolling average barrage flows greater than 2,000 GL/y) showed a marginal decline. Importantly, none of the changes were significant in terms of overall results, as all but one of the CLLMM indicators (3-year rolling average barrage flows greater than 1,000 GL/y) was achieved in both 3200 GL/y scenarios.

Similarly, Murray Mouth bed levels showed no discernible difference between the two 3200 GL/y scenarios over the 114 year modelling period (Figure 16) and the modelled long-term salt export from the Basin is estimated to be 2 million tonnes per year under both scenarios, satisfying the target.

Appendix D shows Murray Mouth bed levels, barrage flows, Lower Lakes water levels and Coorong salinity levels for the period January 2000 to June 2009, which incorporates the Millennium Drought. Similar to the 2800 GL/y scenarios, the differences between the two 3200 scenarios are relatively small and variable, with the subtle differences more closely linked to changes in the environmental demand strategy rather than being a direct response to relaxing constraints.

Figure 16: Murray Mouth bed level exceedance curve for without development, baseline, BP-3200 and BP-3200-RC scenarios.



Impacts of additional volume: BP-2800-RC to BP-3200-RC

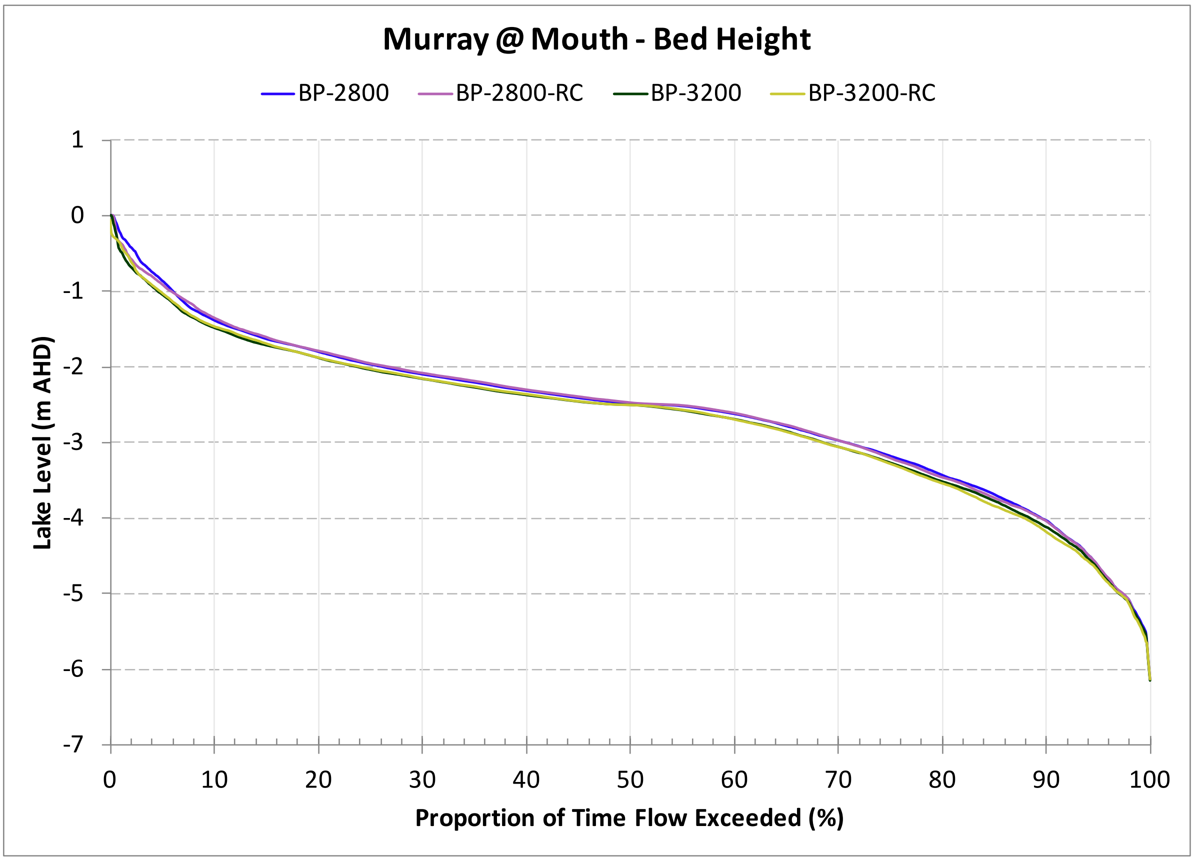
A comparison between the BP-2800-RC results and the BP-3200-RC results (Table 21) indicates improvement in six of the nine salinity and flow CLLMM indicators; with no change in the remaining three indicators. Of particular note is the achievement of the Coorong northern lagoon maximum salinity target of 50 g/L in the BP-3200 RC scenario. In addition, average and maximum Coorong southern lagoon salinities are slightly lower, whilst the 3-year rolling average barrage flows greater than 2,000 GL/y are slightly higher.

There is also small improvement in Murray Mouth bed levels between the BP-2800-RC and BP-3200-RC scenarios; however, the incremental improvement observed with an additional 400 GL/y of recovered volume is minor compared to change from baseline conditions (Figure 17).

Murray Mouth bed levels, barrage flows, Lower Lakes water levels and Coorong salinity levels for the period January 2000 to June 2009 illustrate small, but potentially ecologically significant, improvements in mitigating the impacts of the Millennium Drought in the BP-3200-RC scenario relative to the BP-2800-RC scenario (Appendix D). Examples of the improvements include slightly higher barrage flows and water levels in the Lower Lakes, increased period of an open Murray Mouth and lower salinities (average and maximum) in the north and south Coorong. Differences in the environmental watering strategy explain some of the inter-annual variability shown in various indicators.

The modelled long-term salt export from the Basin is estimated to be 2 million tonnes per year under both the 3200 GL/y scenarios, achieving the target. This represents a slight increase in salt export compared to both 2800 GL/y scenarios (1.95 and 1.96 million tonnes per year respectively). As discussed in MDBA (2012b), these salt load export estimates do not include the projected future increases in salt mobilisation and thus it is considered that all the 2800 and 3200 GL/y scenarios will actually export, on average, more than 2 million tonnes of salt per year from the Basin.

Figure 17: Murray Mouth bed level exceedance curve for the BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.



Combined impacts of additional volume and constraint relaxation: BP-2800 to BP-3200-RC

The combination of constraint relaxation and the availability of additional environmental water had minimal additional effect on the achievement of salinity and flow indicators for CLLMM, relative to the benefits of additional environmental water recovery alone. That is, both the BP-3200 and BP-3200-RC scenarios showed a marked and consistent improvement in CLLMM indicators compared to the BP-2800 scenario, irrespective of whether constraints were maintained or relaxed. The results of the modelling undertaken suggest that the recovered volume, in combination with the environmental watering strategy, is likely to be a more important determinant of outcomes in the Coorong, Lower Lakes and Murray Mouth than addressing constraints.

The minor-scale changes to CLLMM indicators in the constraints relaxed scenarios was not unexpected given that achievement of these indicators is more reliant on volume rather than delivery of peak flows. As such, compared to upstream sites which rely on high flows to inundate mid- to high-parts of the floodplain, environmental outcomes in the Coorong, Lower Lakes and Murray Mouth are unlikely to be particularly sensitive to relaxing key constraints in the southern connected system. In addition, as highlighted previously it is possible that changes to the pattern of river inflows may result in subtle changes in environmental outcomes not reflected by MDBA's flow and salinity CLLMM indicators.

Whilst current modelling of the MDBA Coorong, Lower Lakes and Murray Mouth indicators suggests limited benefit from relaxing constraints, from an operational perspective there may be potentially ecologically important benefits for the CLLMM that arise due to the increased flexibility to deliver environmental water. For example, it is anticipated that there may be situations where relaxing constraints will have the benefit of allowing environmental water managers more options to effectively deliver environmental water to the Coorong, Lower Lakes and Murray Mouth at critical times to mitigate adverse conditions, without compromising delivery of consumptive demands. While situations where channel capacity limit the ability to deliver water to the Coorong, Lower Lakes and Murray Mouth are considered likely to be a rare rather than common occurrence, nonetheless these relatively rare events could be critical to maintaining the site in the longer term.

Table 21: Flow and salinity indicator achievement for the Coorong, Lower Lakes and Murray Mouth site under without development, baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.

Indicator	Target	Without development	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Average salinity (g/L) in Coorong southern lagoon over model period	less than 60 g/L	24	62	44	43	41	41
Maximum salinity (g/L) in Coorong southern lagoon over model period	less than 130 g/L	67	291	119	111	97	98
Max period (days) salinity in Coorong southern lagoon is greater than 130 g/L	0 days	0	323	0	0	0	0
Proportion of years salinity in Coorong southern lagoon < 100 g/L	greater than 95%	100%	82%	96%	99%	100%	100%
Average salinity (g/L) in Coorong northern lagoon over model period	less than 20 g/L	12	29	21	20	20	20
Maximum salinity (g/L) in Coorong northern lagoon over model period	less than 50 g/L	49	148	56	61	47	43
Max period (days) salinity in Coorong northern lagoon is greater than 50 g/L	0 days	0	604	75	114	0	0
Proportion of years 3 year rolling average barrage flow greater than 1,000 GL/y	100%	100%	91%	99%	99%	99%	99%
Proportion of years 3 year rolling average barrage flow greater than 2,000 GL/y	greater than 95%	100%	79%	98%	97%	99%	98%

Baseflows

Similar to the BP-2800-RC baseflow results described above, the BP-3200-RC results (Table 22) suggest little change through relaxation of constraints, consistent with the expectation that altering the constraints would have a greater impact at the high-end of the flow regime.

Table 22: The shortfall to meet the baseflow assessment series in the River Murray under the baseline, BP-3200, and BP-3200-RC scenarios.

Site	Baseline	BP-3200	BP-3200-RC
401010 – Swampy Plains River at Khancoban	0	0	0
401201 – River Murray at Jingellic	0	0	0
409017 – River Murray at Doctor's Point	59.6	17.0	21.9
409025 – River Murray at Yarrawonga Weir	8.4	2.9	2.7
409207 – River Murray at Torrumbarry Weir	89.9	15.0	18.5
414200 – River Murray at Wakool River junction	32.8	1.8	1.4
414203 – River Murray at Euston Weir	54.5	0.3	0.0
425010 – River Murray at Wentworth	99.1	0.4	0.3
426200 – River Murray Flow to SA	141.4	2.9	2.6
426532 – River Murray at Wellington	325.2	39.5	39.9
425007 – Darling River at Burtundy	46.4	4.3	4.0

5.2.2 Hydrological results

To ensure that the modelling scenario was consistent with the targeted water recovery volume, a key part of the modelling process was to check the pattern of both the reduction in diversions and storage levels, relative to baseline conditions. This step was necessary to ensure that the process of developing environmental demands using an environmental account outside of the models did not impact on the long-term reliability of other water users, or result in a reduction in diversions that exceeded the water recovery target.

Table 23 shows that the reduction in diversions for the BP-3200-RC scenario was almost identical to those modelled in the BP-3200 scenario, achieving a 1351 GL/y reduction in diversions compared to the 1349 GL/y target. Similar to the BP-2800-RC scenario and as noted in Section 4.1, the target reduction in diversions was achieved through an iterative process of including environmental demands and scaling irrigation demands. In addition, outflows and losses were very similar in both the BP-3200 and BP-3200-RC scenarios, with a small reduction in outflows and corresponding increase in losses in the BP-3200-RC scenario. These changes are because of the delivery of higher flows when constraints are relaxed.

Similar to the BP-2800 and BP-2800-RC scenarios, Figure 18, Figure 19 and Figure 20 show changes in annual diversions, major storages and end-of-system flow between the two 3200 GL/y scenarios. Figure 18 shows that the pattern of diversions in both scenarios are closely matched and that the patterns reflects baseline conditions.

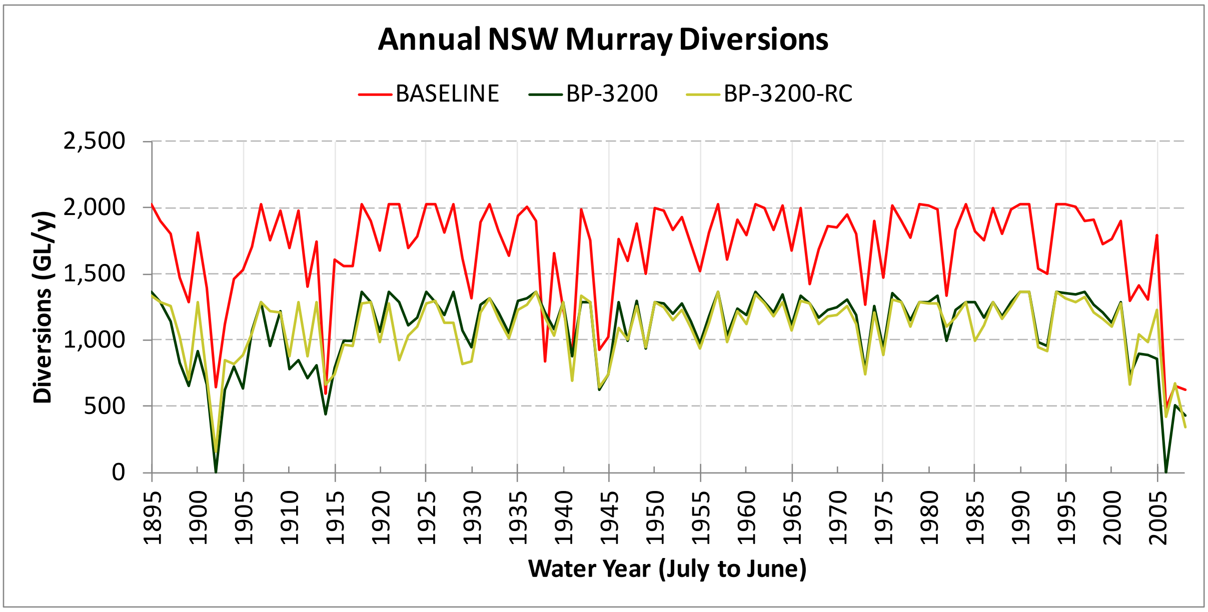
The combined long-term average annual volumes of Dartmouth and Hume Dams are similar in the BP-3200-RC scenario to baseline conditions, although there was some inter-annual variability due to some differences in the timing of environmental demands compared to the historical pattern of consumptive demand. In contrast, consistent with other Basin Plan modelling scenarios, the stored volume in the Lower Murray (Lake Victoria and Menindee Lakes) was consistently higher than under baseline conditions.

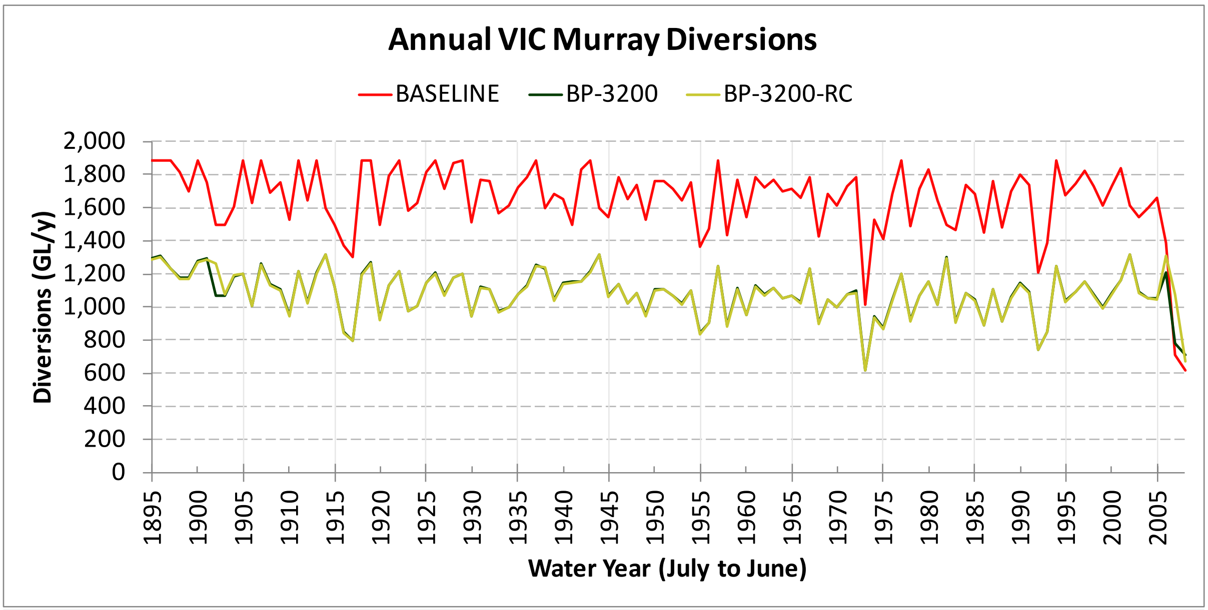
Table 23: Water balance for the Murray system for the without development, baseline, BP-3200 and BP-3200-RC scenarios.

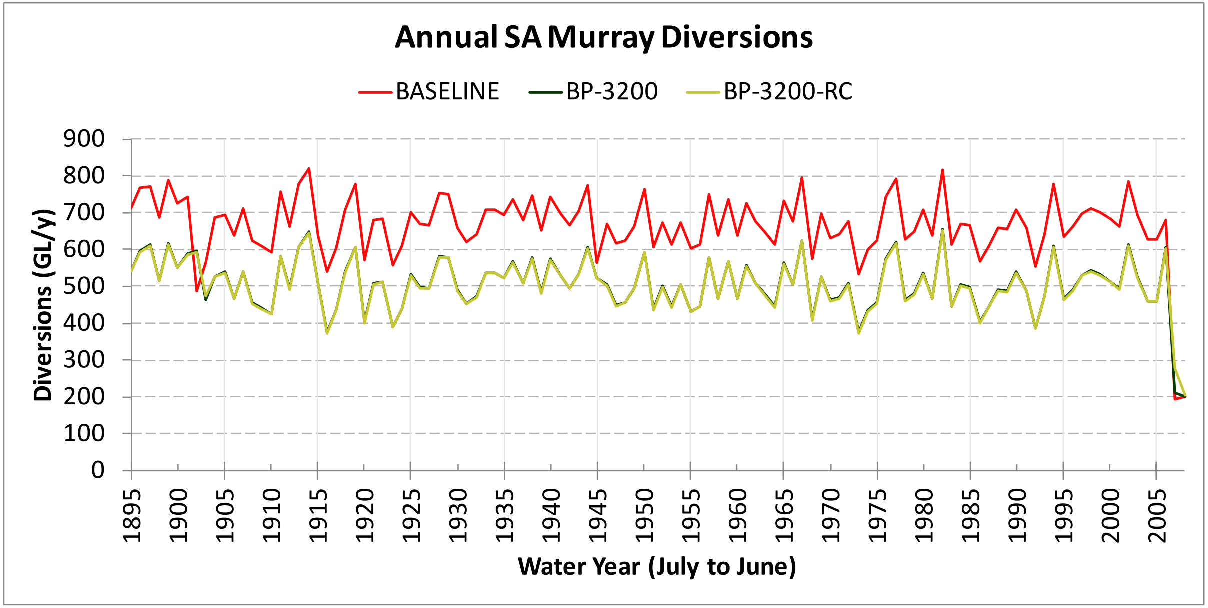
	Without development	Baseline	BP-3200	BP-3200-RC
Inflows:				
NSW	5,940	3,316	4,069	4,069
Victorian	5,782	3,865	4,472	4,473
Shared	4,664	5,201	5,200	5,200
Total Inflows	**16,386**	**12,383**	**13,741**	**13,741**
Diversions:				
NSW Murray	-	1,696	1,099	1,098
NSW Lower Darling	-	55	36	37
Victorian	-	1,654	1,081	1,081
South Australia	-	665	504	504
Total Diversions	**-**	**4,070**	**2,721**	**2,719**
Loss*	**4,008**	**3,225**	**3,543**	**3,552**
Outflow	**12,377**	**5,088**	**7,477**	**7,470**

* Loss includes system loss, unattributed loss in the model and change in storage.

Figure 18: Annual diversions in the River Murray System (for New South Wales, Victoria, South Australia and the Lower Darling) for the baseline, BP-3200 and BP-3200-RC scenarios.




Annual VIC Murray Diversions
BASELINE
BP-3200
BP-3200-RC
Diversions (GL/y)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)


Annual SA Murray Diversions
BASELINE
BP-3200
BP-3200-RC
Diversions (GL/y)
900
800
700
600
500
400
300
200
100
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

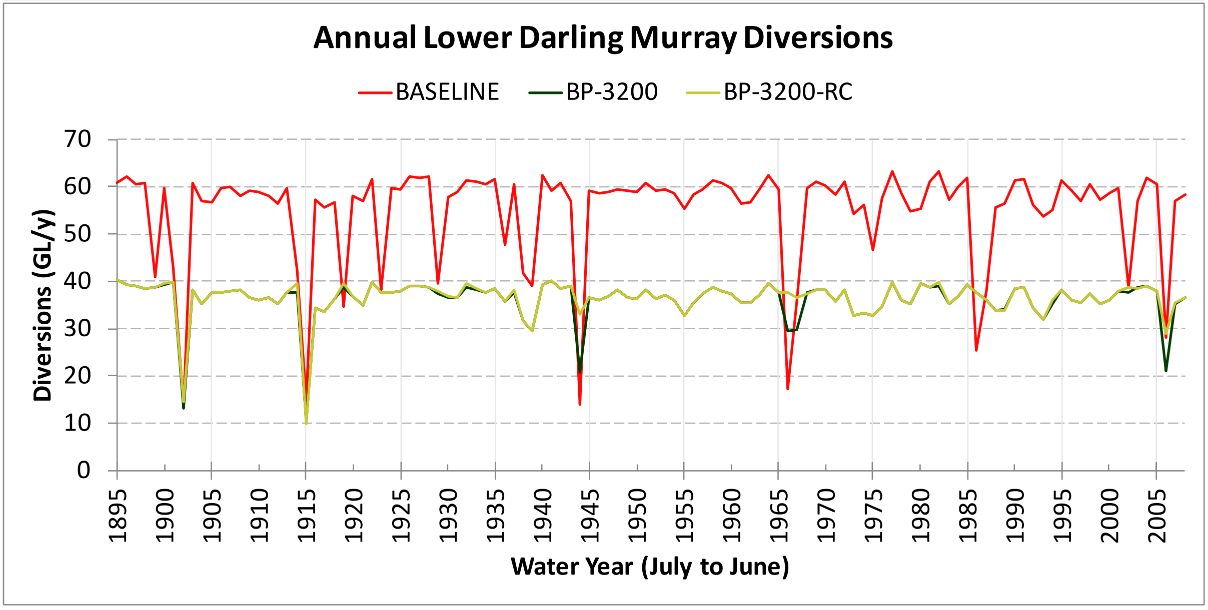
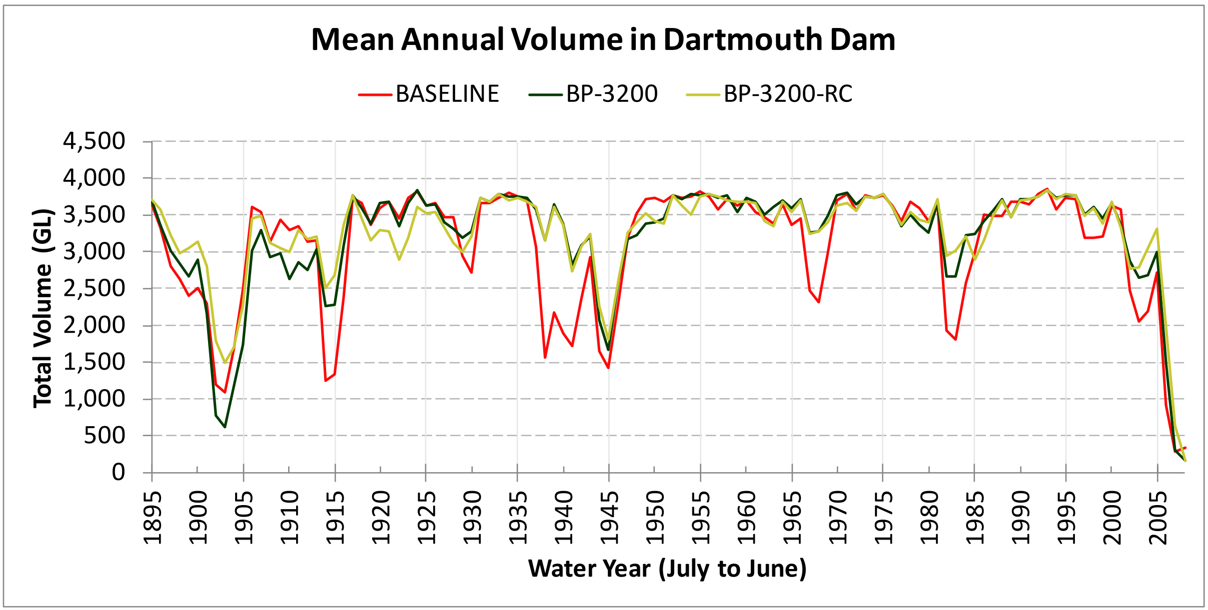
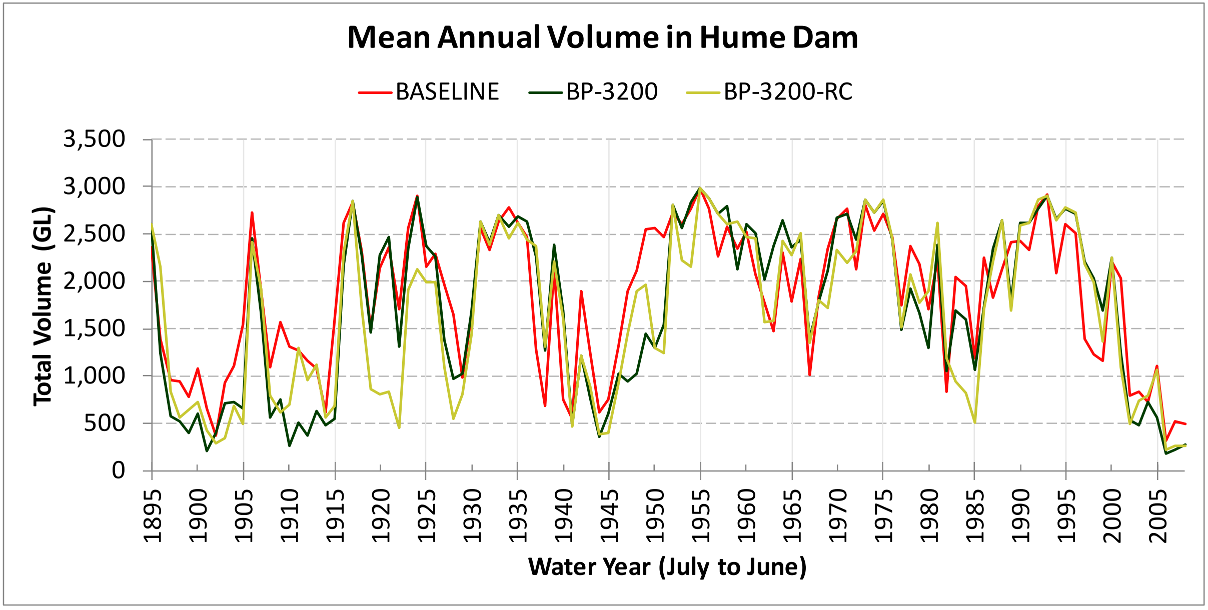
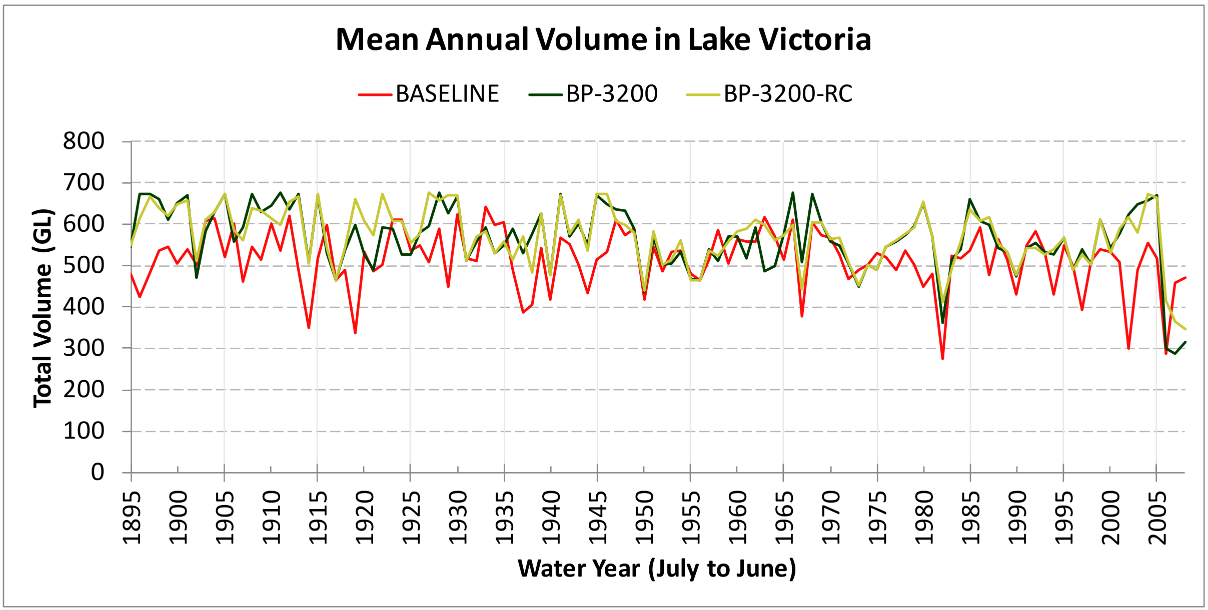

Annual Lower Darling Murray Diversions
BASELINE
BP-3200
BP-3200-RC
Diversions (GL/y)
70
60
50
40
30
20
10
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

Figure 19: Average annual volume in the four main storage in the River Murray System (Dartmouth, Hume, Lake Victoria and Menindee Lakes) for the baseline, BP-3200 and BP-3200-RC scenarios.






Mean Annual Volume in Lake Victoria
BASELINE
BP-3200
BP-3200-RC
Total Volume (GL)
800
700
600
500
400
300
200
100
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

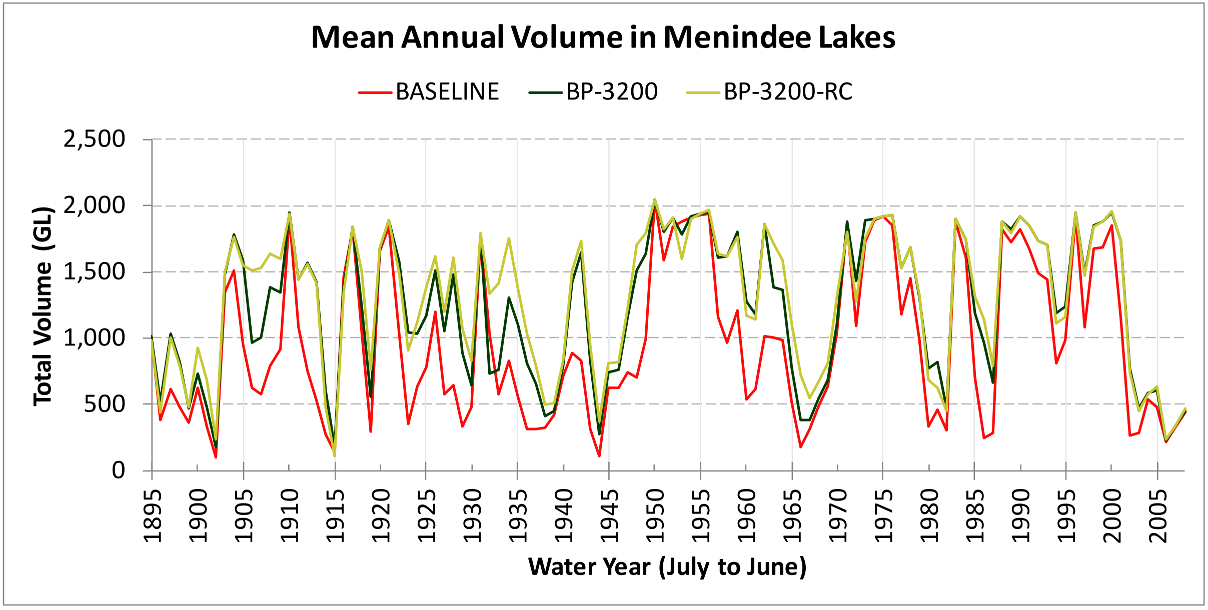
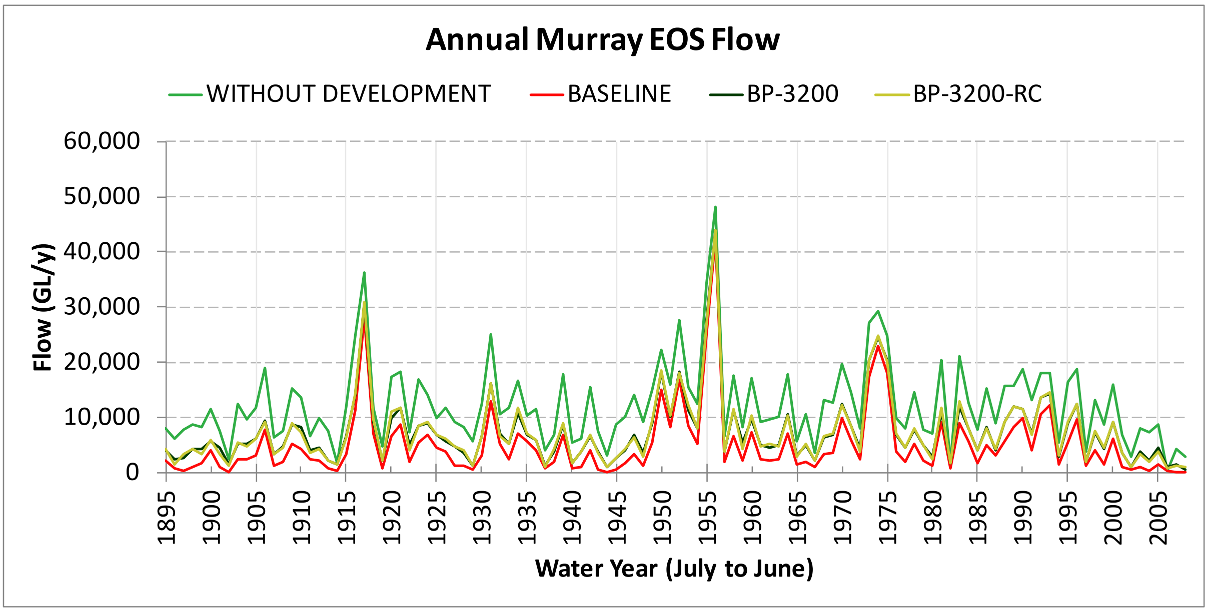

Mean Annual Volume in Menindee Lakes
BASELINE
BP-3200
BP-3200-RC
Total Volume (GL)
2,500
2,000
1,500
1,000
500
0
1895
1900
1905
1910
1915
1920
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
Water Year (July to June)

Figure 20: Annual flows at the end of the River Murray System (barrages) for the without development, baseline, BP-3200 and BP-3200-RC scenarios.



5.3 Dry Spell Analysis

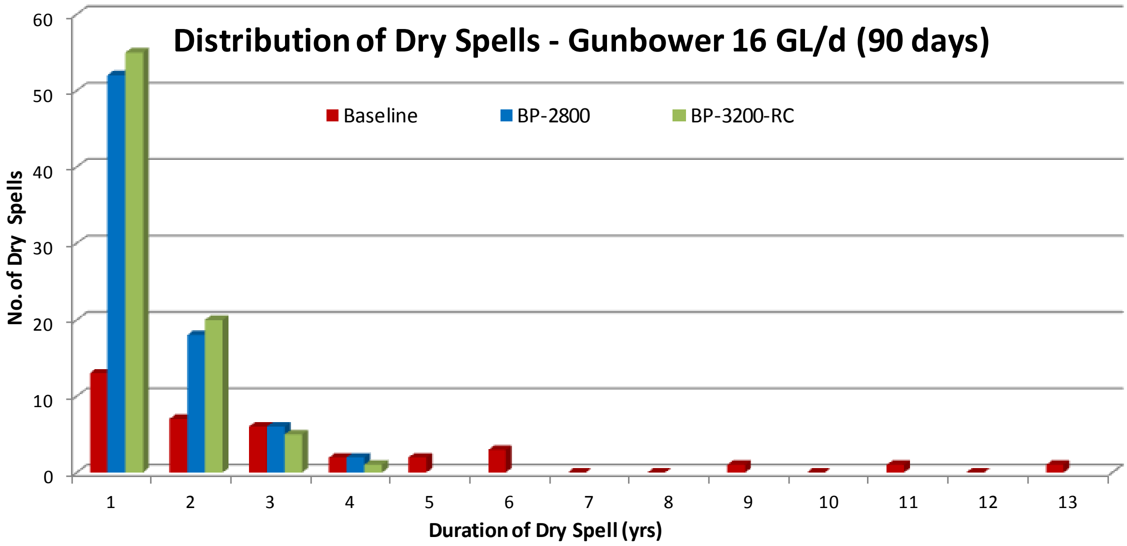
MDBA assessment of model results typically focuses on the long term average frequency of defined flow events at hydrologic indicator sites as described in Sections 5.1 and 5.2. However, the pattern and duration of dry spells are also critical factors contributing to the overall health of water-dependent ecosystems. While the original Basin Plan modelling and environmental event selection process for the relaxed constraints modelling (see Section 3) did not attempt to optimise the reduction in dry spells, there is nevertheless a strong correlation between increased frequency of events and an overall reduction in dry spells. This section presents the results of a dry spell analysis for the relaxed constraints modelling.

The Basin Plan modelling report (MDBA 2012b) listed the modelled duration of the *maximum* dry spell for each flow indicator for the without-development, baseline and Basin Plan (BP-2400, BP-2800, and BP-3200) scenarios. These, along with the maximum dry spells for the relaxed constraints scenarios, are given in Table 13 and Table 14. Table 13 in particular has maximum dry spells for four indicator sites on the River Murray which include events ordered in the demand timeseries at that site and achieved within 10% of the flow indicator threshold and duration (see Appendix C for further explanation). This analysis showed that there were several indicators where the maximum dry spell substantially reduced as a result of including these events.

An example of a significant reduction in maximum dry period is demonstrated by the 16,000 ML/d for 90 days flow indicator at the Gunbower-Koondrook-Perricoota Forest hydrologic indicator site which reduced from 13 years under baseline conditions to 4 years in all of the Basin Plan scenarios (Table 13). This reduction in maximum dry period is illustrated in Figure 22 which shows the distribution of the length of dry spells between 16,000 ML/d for 90 days events. The red bars represent the baseline conditions dry spells, which range from 1 year up to a maximum of 13 years. In contrast, both the BP-2800 scenario (blue bars) and the BP-3200-RC scenario (green bars) demonstrated a reduced maximum dry period of 4 years, and there was an associated increase the number of shorter dry periods of duration 1 – 2 years (Figure 22).

The length of a dry period has important implications for ecological outcomes. For example, the 16,000 ML/d for 90 days flow indicator at the Gunbower-Koondrook-Perricoota Forest hydrologic indicator site is primarily intended to inundate low-level wetlands and it is known that the viability of wetland plant seeds declines over time. Ribbon weed (*Vallisneria australis*), a common aquatic plant, has seed that will remain viable in dry wetland sediments for up to nine years (Roberts and Marston 2011). Exceedance of this seed viability threshold, as occurs under baseline conditions, will result in loss of wetland resilience and productivity. In contrast, the Basin Plan scenarios were effective at reducing the maximum dry periods to within known resilience periods for wetland communities at this site.

Figure 21: A histogram showing the distribution of dry spell lengths between 16,000 ML/d (90 day) events at the Gunbower-Koondrook-Perricoota Forest hydrologic indicator site.



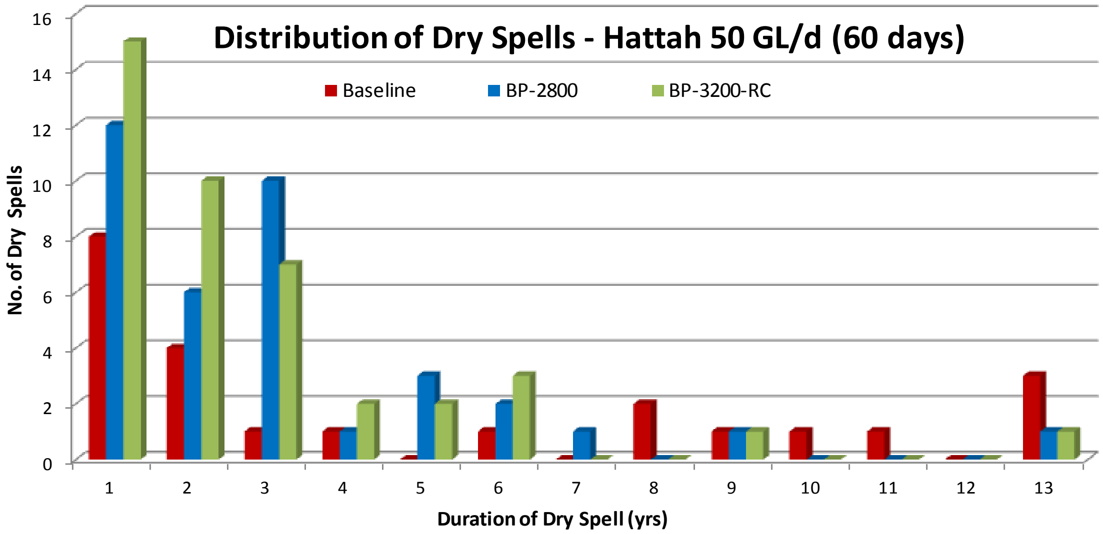
The maximum dry spell duration is a useful indicator of water-dependent community health; however, it includes some inherent limitations which could influence any interpretation of the results:

- The indicator can be substantially affected by the success (or failure) of a single watering event, limiting the statistical significance of the result. These critical single watering events often occur during long, dry periods and without severely changing access of consumptive users even a larger environmental water portfolio may not address the longest dry spell periods as allocations to all users are low. Accordingly, the availability of water to reinstate critical overbank flow events that often define the maximum dry period is limited.
- The indicator only identifies the maximum dry spell and does not show changes to other dry spell lengths over the complete 114-year modelling period, and may therefore underestimate the potential benefits of a Basin Plan watering strategy.
- The indicator does not take account of the health of the water-dependent communities at the onset of a dry spell. This health will be partially dependent on the effectiveness of watering between dry spell events, which will have a bearing on the resilience of the community to endure a dry spell.
- The environmental event selection process was not optimised to reduce the duration of maximum dry spells, hence the modelling results may not provide an accurate indication of the potential to improve the maximum dry period in practice.

To illustrate these limitations, Figure 22 shows the distribution of the length of dry spells between 50,000 ML/d (60 day) events at the Hattah Lakes indicator site. The red bars indicate that under baseline conditions there were 23 dry spells over the 114-year modelling period, with the duration of eight of these spells being one year (i.e. watering events in consecutive years) and the remainder having a duration of between two and 13 years. The longest dry period (13 years) did not change in the BP-2800 and BP-3200-RC scenarios; hence the maximum dry indicator would suggest no improvement resulting from the Basin Plan watering strategy included in the models. However, the number of 13 year maximum dry periods was reduced from 3 events to one in the Basin Plan scenarios which corresponds to a reduction of environmental stress associated with a 13 year interval between watering events.

In addition, there was a significant improvement in the overall *distribution* of these dry spells as a result of the watering strategy. The blue bars (BP-2800) indicate a substantial shift towards shorter dry periods. This improved further in the BP-3200-RC scenario (green bars), in which the number of one- and two-year dry spells increased. These spells are associated with two- and three-year wet periods which are important for improving resilience of flood-dependent ecosystems

Figure 22: A histogram showing the distribution of dry spell lengths between 50,000 ML/d (60 day) events at the Hattah Lakes hydrologic indicator site.



Further analysis presented in Figure 23 and Table 24 complements the maximum dry spell results in Table 13 by measuring changes to the general characteristics of all dry spells. Instead of examining the length of the single longest dry spell, this analysis includes all dry spells over the 114-year modelling period. This analysis is particularly relevant given, as highlighted above, the maximum dry statistics are often determined by a critical single watering event that occur during long, dry periods when allocations are low. Consequently, the ability to address dry spells is limited and an increase in the size of the environmental water portfolio may not be sufficient to enable these dry spells to be addressed.

To carry out this more comprehensive analysis, a 'dry spell duration curve' was constructed for each of the flow indicators at a number of hydrologic indicator sites on the River Murray. Similar to flow duration curves, these show the percentage of dry spells that had a duration less than a given value. The maximum dry period corresponds to the 100th percentile dry spell on a dry spell curve. The 50th percentile value is the median length of a dry spell (measured in years); that is, 50% of dry spell events have a period shorter than this value, and the remaining 50% have a longer period.

Figure 23 shows a dry spell duration curve for the 80,000 ML/d (30 day) flow indicator at the Riverland–Chowilla Floodplain hydrological indicator site. This representation ranks dry spells by their length: the longest dry spells are located towards the right-hand side of the figure, and the shortest dry spells (i.e. one year) are located to the left. A rapid increase in the curve when moving from left to right (e.g. baseline; red) indicates an increased tendency towards *long* dry spells; a relatively flat curve (e.g. without development; dashed) indicates that *short* dry spells are more common. The figure specifically emphasises the duration of the 75th percentile dry spell, which provides a useful indicator to compare dry spell changes between model scenarios. The 75th percentile dry spell indicator highlighted below corresponds to the length of the dry spell, measured in years, that encompasses 75% of all dry spell events in the 114 year modelling sequence. That is, 75% of dry spells will have a duration shorter than this value, and 25% will have a longer duration.

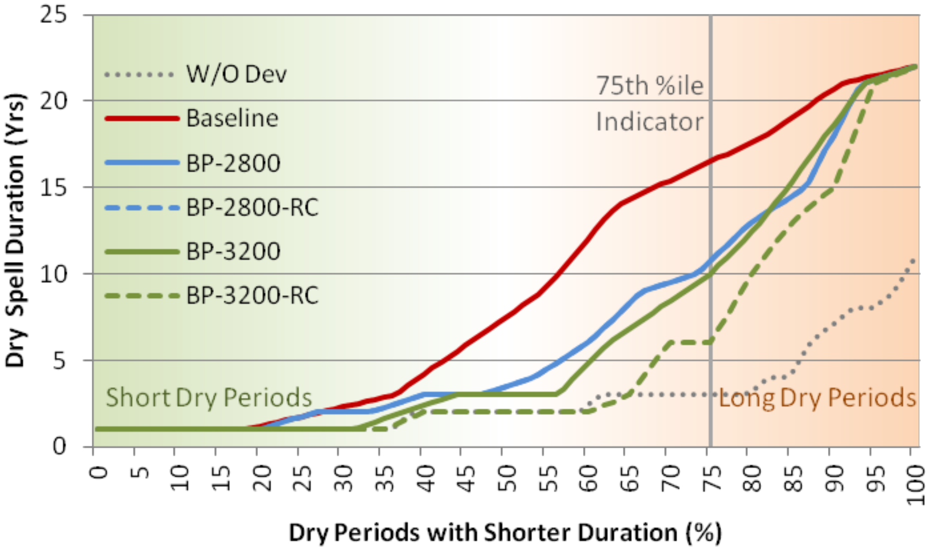
Expressed differently, this indicator represents the dry spell period for three quarters of all events, and therefore isolates the 25% of events with the longest dry spell — an inspection of the baseline model output data indicates that the dry periods with the greatest potential for ecological impact generally comprise the longest 25% of dry spells.

Figure 23 shows that under without-development conditions, 75% of the dry spells between environmental events assessed as successful for the 80,000 ML/d flow indicator at the Riverland–Chowilla floodplain hydrologic indicator site lasted three years (or less), as marked by the intersection of the dotted and grey lines. The equivalent value under baseline conditions was 16.5 years. This value has improved to 10.8 years in the BP-2800 and BP-2800-RC scenarios (blue line and blue dashed line; these results were equivalent, hence the lines overlap), and further improved to 6.0 years in the BP-3200-RC scenario (dashed green line). The figure indicates that only 20% of the without-development dry spell period durations were maintained under baseline conditions; however, this proportion has increased in the BP-3200-RC scenario to 66%.

To quantify the general changes to the durations of all dry spells, the value of this 75th percentile dry spell indicator (labelled τ_{75}) is given in Table 24 for the baseline and BP scenarios for a number of River Murray hydrologic indicator sites. This indicator is dependent on the entire spectrum of dry spells; hence it provides a more robust measure of the ability to improve the overall characteristics of dry spells through a Basin Plan watering strategy. Furthermore, the value of τ_{75} is influenced by the number of one-year dry spells. These represent periods in which environmental watering events occur in consecutive years, an important factor influencing the resilience of a water-dependent community to endure relatively long dry periods.

There was a consistent reduction in the τ_{75} dry spell duration for all actively managed indicators when comparing the BP-2800 and BP-3200 scenarios to the baseline scenario. The only indicators where there was an increase (the 50,000 and 60,000 ML/d indicators at Barmah–Millewa Forest, and the 125,000 ML/d indicator at the Riverland–Chowilla Floodplain) were those for which the flows are considered to be too high for active management. These changes are an indirect (and unintended) result of the altered spill patterns in the Basin Plan model scenarios.

Figure 23: Dry spell duration curve for the 80,000 ML/d (30 day) indicator at the Riverland–Chowilla Floodplain hydrological indicator site*. The 75th percentile indicator (τ_{75}) is marked in grey. The BP-2800 and BP-2800-RC scenarios produced equivalent results, hence their lines overlap.



* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

The relaxation of constraints in the models led to an increase in the frequency of mid- to high-flow events, most prominently in the BP-3200-RC scenario. This improvement in the mid- to high-flow event frequencies was also reflected in their dry spell results—a comparison of the BP-3200-RC scenario to the BP-2800 and BP-3200 scenarios showed an improvement in the τ_{75} dry spell duration for the following flow indicators:

- Barmah–Millewa Forest – 35,000 ML/d for 30 days
- Gunbower–Koondrook–Perricoota Forest – 40,000 ML/d for 60 days
- Hattah Lakes – 70,000 ML/d for 42 days
- Hattah Lakes – 85,000 ML/d for 30 days
- Riverland–Chowilla Floodplain – 60,000 ML/d for 60 days
- Riverland–Chowilla Floodplain – 80,000 ML/d for 30 days.

These changes were most pronounced for the 85,000 ML/d (Hattah Lakes) and 80,000 ML/d (Riverland–Chowilla Floodplain) indicators. These events are considered to be at the limit of deliverable capacity even with the relaxation of constraints, and the relaxation of constraints (with a recovered volume of 3200 GL/y) significantly improved the τ_{75} dry spell durations from 14 to 9 years and 12.3 to 6 years respectively (Table 24).

Table 24: The 75th percentile dry spell indicator (τ_{75}) for a number of flow indicators for River Murray system. Grey cells mark those indicators for which no environmental demands were included in the model.

Hydrologic Indicator site	Flow indicator[2]	75th percentile dry spell indicator (τ_{75}; years)[1]					
		W/O Dev	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Barmah–Millewa Forest	12,500 ML/d for 70 days (Jun-Nov)	1.0	2.0	1.0	1.0	1.0	1.0
	16,000 ML/d for 98 days (Jun-Nov)	2.0	4.5	2.0	2.3	2.0	2.0
	25,000 ML/d for 42 days (Jun-Nov)	2.0	4.0	3.0	3.0	3.0	3.0
	35,000 ML/d for 30 days (Jun-May)	2.0	6.0	4.0	4.0	5.0	4.0
	50,000 ML/d for 21 days (Jun-May)	3.0	6.0	9.0	13.0	6.0	11.0
	60,000 ML/d for 14 days (Jun-May)	3.5	9.0	12.0	14.0	10.8	14.3
	15,000 ML/d for 150 days (Jun-Dec)	3.0	14.0	3.3	3.0	4.0	3.0
Gunbower–Koondrook–Perricoota Forest	16,000 ML/d for 90 days (Jun-Nov)	1.0	4.0	2.0	2.0	2.0	2.0
	20,000 ML/d for 60 days (Jun-Nov)	1.0	3.0	2.0	2.0	2.0	2.0
	30,000 ML/d for 60 days (Jun-May)	2.0	6.0	3.0	3.0	3.0	3.0
	40,000 ML/d for 60 days (Jun-May)	3.0	15.0	8.5	7.0	7.5	6.0
	20,000 ML/d for 150 days (Jun-Dec)	3.0	21.0	4.0	4.0	7.0	4.0
Hattah Lakes	40,000 ML/d for 60 days (Jun-Dec)	2.0	4.5	3.0	3.0	3.0	3.0
	50,000 ML/d for 60 days (Jun-Dec)	2.5	8.5	3.0	4.0	5.0	3.0
	70,000 ML/d for 42 days (Jun-Dec)	3.0	13.0	9.0	9.0	9.3	6.5
	85,000 ML/d for 30 days (June-May)	3.0	15.0	13.0	13.0	14.0	9.0
	120,000 ML/d for 14 days (June-May)	6.0	17.5	17.5	17.5	17.5	17.5
	150,000 ML/d for 7 days (June-May)	9.0	20.0	20.0	20.0	19.0	19.0
Riverland–Chowilla Floodplain	20,000 ML/d for 60 days (Aug-Dec)	1.0	3.0	2.0	2.0	1.0	2.0
	40,000 ML/d for 30 days (Jun-Dec)	1.0	3.0	2.0	2.0	2.0	2.0
	40,000 ML/d for 90 days (Jun-Dec)	2.0	7.8	3.0	3.0	3.0	3.0
	60,000 ML/d for 60 days (Jun-Dec)	3.0	13.0	6.0	5.8	6.0	5.8
	80,000 ML/d for 30 days (June-May)	3.0	16.5	10.8	10.8	12.3	6.0
	100,000 ML/d for 21 days (June-May)	7.5	19.0	20.0	19.0	18.0	19.0
	125,000 ML/d for 7 days (June-May)	9.3	31.0	31.0	31.0	31.0	34.0

[1] The 75th percentile dry spell indicator corresponds to the length of the dry spell, measured in years, that encompasses 75% of all dry spell events in the 114 year modelling sequence. . Expressed differently it represents the dry spell period for three quarters of all events, excluding 25% of the events with the longest dry spell.

[2] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

6 Conclusions

Overall, the model results indicate that the relaxation of key constraints would have a positive effect on the ability to deliver high-flow events. These high-flow events are particularly important for the inundation of large areas of natural floodplain, and the modelling work suggests that relaxing flow constraints would allow environmental water to be delivered in a way that inundates these areas for longer periods and at a greater frequency.

The BP-2800-RC scenario indicates that with 2800 GL/y of water recovery, constraint relaxation would allow environmental water managers to enhance the delivery of flows at the mid- to high-end of the flow regime. Relaxing constraints would enable managers to extend the duration and peak of flow events, increasing the area of floodplain being watered. Whilst the resulting environmental benefits are likely to be important to floodplain health, the existing Basin Plan flow indicators are too ‘coarse’ to show these additional benefits.

The BP-3200-RC scenario indicates that the combination of constraint relaxation and an additional 400 GL/y of available environmental water is likely to enable substantially increased environmental benefits for the floodplain of the Lower Murray. This model scenario has shown some significant benefits as measured by the mid- to high-environmental flow indicators for the four indicator sites along the River Murray.

Scenario BP-2800-RC – floodplain outcomes

In the BP-2800-RC scenario the relative coarseness of the flow indicators generally meant they were not able to detect smaller positive changes to the flow regime. There were nevertheless more subtle changes in the flow regime and hence a more detailed analysis was undertaken. Box 7 highlights the main outcomes of relaxing constraints with 2800 GL/y of water recovery.

Box 7: Summary of environmental benefits from relaxing flow constraints with 2800 GL/y of water recovery.

Environmental benefits of relaxing constraints — 2800 GL/y

- Increased flow peak and duration for existing inundation events in the southern system
- The achievement of a high-flow target in the Upper Murray (target frequency now met for the Barmah indicator: 35,000 ML/d for 30 days)
- Average number of high-flow days per year has increased in the Lower Murray.

Scenario BP-3200-RC – floodplain outcomes

Compared to the BP-2800 scenario, the BP-3200-RC scenario represented the combination of additional water recovery (to provide a further 400 GL/y for the environment) and relaxing constraints (to improve the ability to deliver environmental flows). The results indicated that this combination of actions could have positive impacts for the flood-dependent ecosystems along the River Murray. These benefits are summarised in Box 8. Furthermore, unlike the BP-2800-RC scenario above, these flow regime changes were significant enough to increase the number of environmental flow indicators achieved.

Box 8: Summary of environmental benefits from relaxing flow constraints with 3200 GL/y of water recovery.

Environmental benefits of relaxing constraints — 3200 GL/y

- a further increase to the *flow peak and duration* of inundation events in the southern system
- achievement of several *high-flow targets at four River Murray hydrologic indicator sites*, indicating the potential for improved environmental outcomes for the mid-to-high level floodplain and colonial waterbird breeding:
    - 35,000 ML/d at Barmah–Millewa Forest
    - 40,000 ML/d at Gunbower–Koondrook–Perricoota Forest
    - 20,000 ML/d (150 days) at Gunbower–Koondrook–Perricoota Forest
    - 70,000 ML/d at Hattah Lakes
    - 80,000 ML/d at Riverland–Chowilla Floodplain
- achievement of 17 of the 18 'active management' flow indicator targets in the River Murray
- limited improvement in achievement of Coorong, Lower Lakes and Murray Mouth flow and salinity indicators compared to the benefits of additional environmental water recovery alone as represented in the BP-3200 scenario.

MDBA modelling has targeted the delivery of flows to 18 flow indicators for indicator sites along the River Murray. Eleven of these indicators were achieved in the BP-2800 scenario. The BP-2800-RC scenario suggested positive (but marginal) changes to the flow regime with no overall improvement to the flow indicator achievement count, while some improvement was made in the BP-3200 scenario with constraints in place (13 achieved).

In contrast, the BP-3200-RC scenario has achieved 17 of the 18 flow indicators for the Murray, including the previously unattained high-flow indicators for the Gunbower–Perricoota–Koondrook Forest (40,000 ML/d) and Riverland–Chowilla Floodplain (80,000 ML/d). Both of these high-flow indicators are associated with events considered to be at the limit of regulated deliverability, and their achievement in this scenario suggests potential benefits of combining additional environmental water with flow constraint relaxation.

Table 25: Number (out of eighteen) of actively managed environmental flow indicators achieved on the River Murray for each Basin Plan scenario[*]. The scenarios discussed in this report are shaded in grey.

Scenario	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Number of Flow Indicators Achieved — River Murray	0/18 (0%)	11/18 (61%)	11/18 (61%)	13/18 (72%)	17/18 (94%)

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

The scenarios presented in this report represent only one of a large number of alternative ways in which environmental water could be used—with differing outcomes across different parts of the flow regime and different environmental outcomes. The trade-offs between these competing environmental water requirements for a given volume of water recovered have not been fully explored. In addition, actual environmental outcomes at both a valley- and Basin-wide scale will depend on:

- the types of water recovery works and measures implemented
- the mix of water entitlements purchased from the system (where, how many and type)
- the extent and ways in which flow delivery constraints are addressed
- the extent to which assumed water management and water sharing policies are implemented (e.g. the use of return flows)
- prioritisation on the use of environmental water (e.g. the relative priority assigned to sites and different flow events)
- the characteristics of the future climate compared to the historical climate modelled.

The scenarios therefore give a general indication of the direction and magnitude of change that may be possible with the options assessed, rather than describing an exact outcome from those options.

7 References

BOM (2012) Bureau of Meteorology, Victorian Flood Class levels North of Divide, http://www.bom.gov.au/vic/flood/floodclass_north.shtml, accessed 1 June 2012.

DSE (2011) Overbank flow recommendations for the lower Goulburn River, Victorian Department of Sustainability and Environment, February 2011.

Jones G, Hillman T, Kingsford R, McMahon T, Walker K, Arthington A, Whittington J and Cartwright S (2002) Independent Report of the Expert Reference Panel on Environmental Flows and Water Quality Requirements for River Murray System. Cooperative Research Centre for Freshwater Ecology. Report to the Murray–Darling Basin Ministerial Council. February 2002.

MDBA (2011a) Comparison of Water Course Diversion Estimates in the Guide to the Proposed Basin Plan with other Published Estimates, Murray–Darling Basin Authority Technical Report No. 2011/01, Version 2, November 2011.

MDBA (2011b) PROPOSED Basin Plan – a draft for consultation, MDBA Publication no: 192/11, Murray–Darling Basin Authority, Canberra.

MDBA (2011c) The proposed 'environmentally sustainable level of take' for surface water of the Murray–Darling Basin: Methods and outcomes, MDBA Publication no: 226/11, Murray–Darling Basin Authority, Canberra.

MDBA (2011d) Water Resource Assessments for without development and baseline conditions: Supporting information for the preparation of the Guide to the Proposed Basin Plan. MDBA Technical Report 2010/20, Version 2. November 2011.

MDBA (2012a) Assessment of environmental water requirements for the proposed Basin Plan: Lower Goulburn River Floodplain, Murray–Darling Basin Authority, http://www.mdba.gov.au/draft-basin-plan/science-draft-basin-plan/assessing-environmental-water-requirements

MDBA (2012b), Hydrologic modelling to inform the proposed Basin Plan - methods and results, MDBA publication no: 17/12, Murray–Darling Basin Authority, Canberra.

Page KJ, Read A, Frazier P and Mount N (2005) The effect of altered flow regime on the frequency and duration of bankfull discharge: Murrumbidgee River, Australia, River Research and Applications, vol. 21, no. 5, pp. 567–578.

Roberts J and Marston F (2011) Water regime for wetland and floodplain plants, A sourcebook for the Murray Darling Basin. National Water Commission, Canberra, ACT.

SKM (2006) Goulburn Campaspe Loddon Environmental Flow Delivery Constraints Study, Sinclair Knight Merz Pty Ltd, 23 November 2006.

Water Technology (2010) Goulburn River Environmental Flows: Hydraulic model application and affected asset assessment, Environmental flow scenarios. Water Technology report for the Goulburn Broken CMA.

Appendix A. Key constraints in the southern connected system

The 8 key constraints tested by the modelling described in this report are summarised in Figure 3 and Table 1 of the report. This appendix contains further information on these constraints.

A.1. River Murray

The key physical and operational constraints in the River Murray that have been relaxed in the modelling are:

- channel capacity at Doctor's Point
- channel capacity at downstream of Yarrawonga.

A.1.1. Channel capacity at Doctor's Point (Figure 3, location 1)

The regulated releases from Hume are managed so that flow at Doctor's Point does not exceed 25,000 ML/d. This is to minimise overbank flows and the associated inundation of agricultural land. This constraint limits opportunities for augmenting high flows from downstream tributaries to achieve some of the Basin Plan flow objectives for key sites such as Barmah–Millewa Forest, Gunbower–Koondrook–Perricoota forests, Hattah Lakes and associated flood-dependent ecosystems in river reaches between Hume and Wentworth.

The relaxed constraints modelling described in this report assumed an increase of regulated releases up to 40,000 ML/d.

A.1.2. Channel capacity downstream of Yarrawonga (Figure 3, location 2)

There is a natural channel capacity constraint downstream of Yarrawonga known as the Barmah Choke, which is considered as an operational constraint as water begins flooding adjacent floodplains and wetlands at around 10,600 ML/d. In order not to flood Barmah–Millewa Forest unseasonally, releases for irrigation are limited to maintain flow downstream of Yarrawonga below 10,600 ML/d during summer and autumn, but are increased to allow 22,000 ML/d during Spring–Winter seasons under baseline conditions (MDBA, 2011d & 2012b).

In the modelling for the proposed Basin Plan (MDBA, 2012b), the limit was increased to 40,000 ML/d during times of environmental water delivery, while original flow constraints were maintained at other times. The constraint relaxed scenarios made use of the same 40,000 ML/d limit.

A.2. Menindee Lakes and the Lower Darling

Regulated releases from Menindee Lakes (Figure A.1) are currently constrained in the model to an upper flow of 279 GL/m (~9,300 ML/d), limiting the ability to deliver water from these storages towards high-flow environmental events in the Lower Darling and Lower Murray systems. This upper limit was based on two main constraints in the Menindee Lakes system and the Lower Darling River, as detailed below.

A.2.1. Menindee Lakes outlet capacity (Figure 3, location 3)

The release capacity of Lakes Menindee and Cawndilla substantially decreases as the storage volume decreases, such that when the combined storage volume of the lakes approaches 480 GL, a flow of 9,300 ML/d down the Darling River can only be supplied from Lakes Pamamaroo and Wetherell. NSW has expressed concerns that increasing the water drawn from Lakes Pamamaroo and Wetherell for environmental purposes would result in water stranded in Lakes Menindee and Cawndilla, and would impact the reliability of supply to Broken Hill and Lower Darling irrigators. Thus the release capacity at Lake Menindee is a major flow delivery constraint. Furthermore, high river flows can also limit the release capacity of the Menindee Lakes system.

NSW has identified a range of other constraints between flows of 9,300 and 18,000 ML/d which could potentially be overcome (pers. comm. Paul Simpson (NOW), 17 April 2012); however, flows above 18,000 ML/d in the Lower Darling River result in the flooding of private land, including houses in the township of Menindee. Therefore, the outlet capacity of Lake Menindee was increased for the relaxed constraints modelling to 18,000 ML/d to represent an improved ability of Lakes Menindee and Cawndilla to deliver the desired environmental flows.

A.2.2. Darling Anabranch (Figure 3, location 4)

Because of the natural morphology of the river system, flows down the Great Darling Anabranch (Figure A.2) will commence when the flow in the Darling River exceeds 9,300 ML/d. Therefore, an operating rule in the model used for previous Basin Plan scenarios limited the order at Weir 32 (Figure A.1) to a maximum of 279 GL/m (~9,300 ML/d) to minimise 'losses' down the anabranch.

For the relaxed constraints scenarios presented in this report, a regulator has been placed at the location where high flows in the Darling would normally flow across to the Darling Anabranch bifurcation site to prevent environmental releases above 9,300 ML/d from entering the anabranch and thereby maximise the flows reaching the Lower Murray system.

The regulator on the Darling Anabranch was closed only when there was a downstream environmental demand in the River Murray—to allow more water to pass down the Darling River to the Murray. At all other times the regulator remained open allowing flows to enter the Darling Anabranch (noting that explicit environmental demands for the Lower Darling are not included in the modelling).

Figure A.1: The Menindee Lakes System

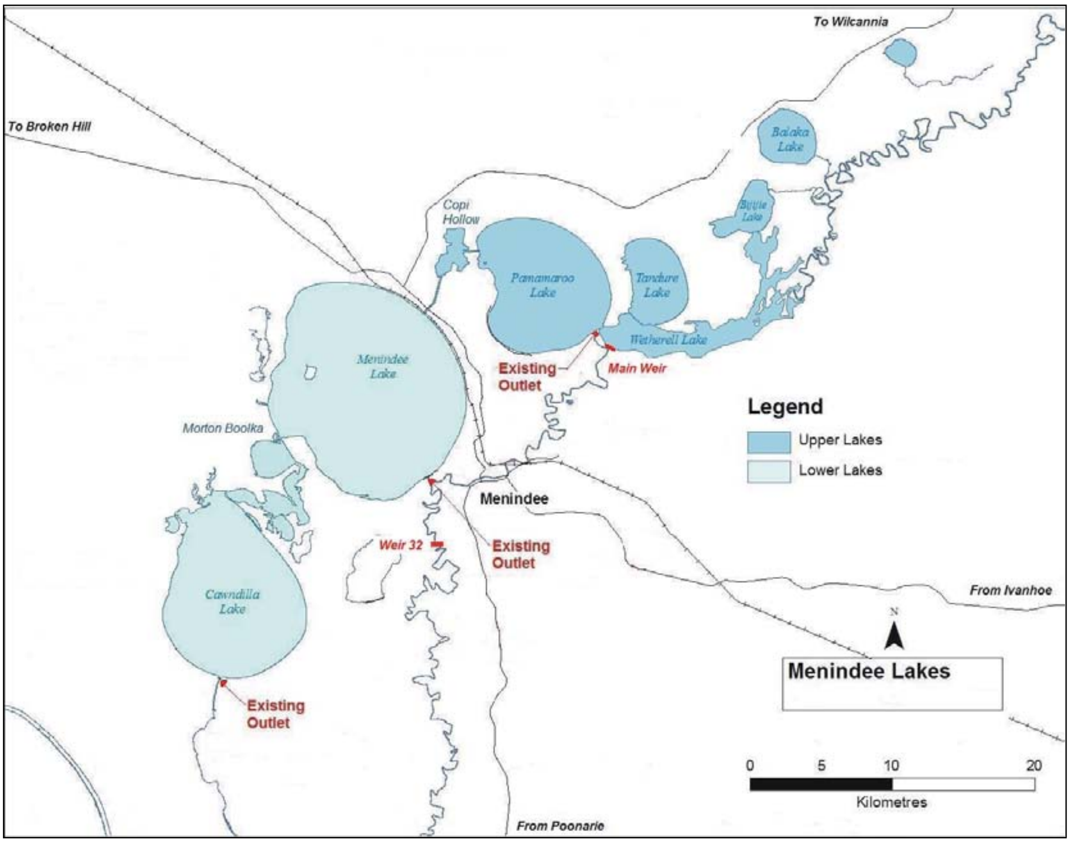
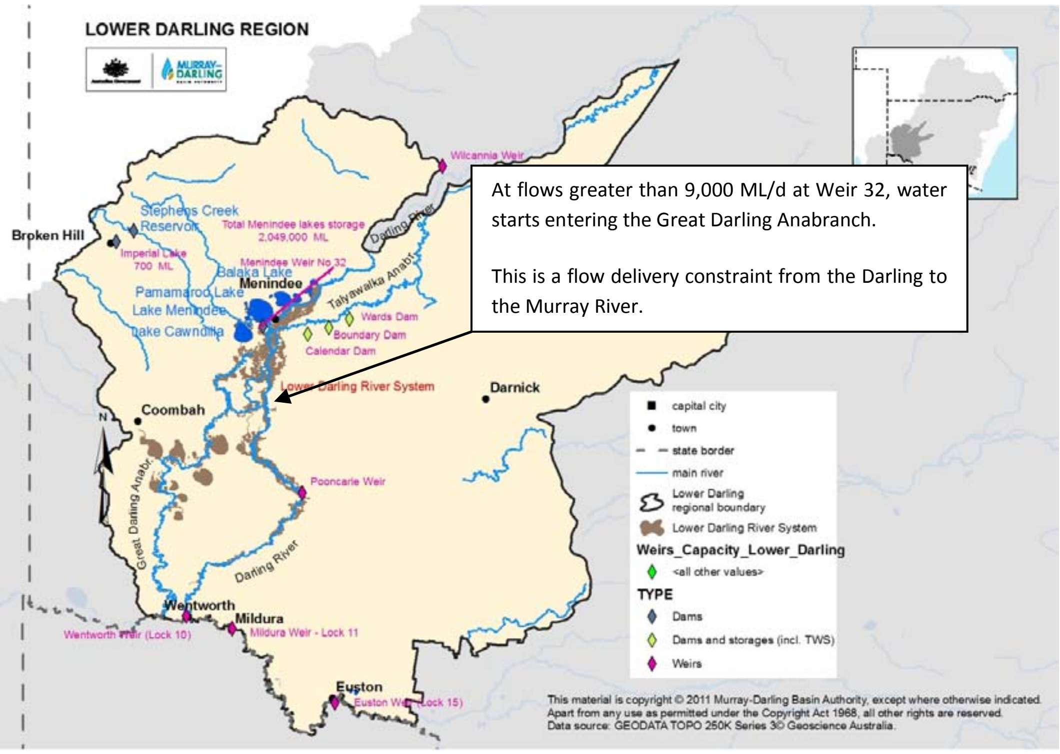


Figure A.2: The Lower Darling



At flows greater than 9,000 ML/d at Weir 32, water starts entering the Great Darling Anabranch.

This is a flow delivery constraint from the Darling to the Murray River.

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A.3. Murrumbidgee River system

The physical and operational constraints in the Murrumbidgee River system that were relaxed in the modelling are:

- regulated flow rates at Gundagai
- regulated flow rates at Balranald.

These constraints and the extent to which they have been relaxed are described in sections below. However, it is worth noting that there is an additional key constraint in the Murrumbidgee system, i.e. regulated flows in the Tumut River have to be limited to 9,000 ML/d at Oddy's Bridge and 9,300 ML/d at Tumut to prevent flooding at Tumut and to minimise bed and bank erosion. These constraints are represented in the Murrumbidgee model and given that these constraints would be hard to overcome, they were not relaxed in the modelling for this study.

A.3.1. Channel capacity at Gundagai (Figure 3, location 5)

The NSW Water Sharing Plan for the Murrumbidgee stipulates that releases from Burrinjuck and Blowering are to be limited so that the flow at Gundagai does not exceed 32,000 ML/d. This is based on the risk of flooding around the Gundagai area and, specifically, Mundarlo Bridge. This constraint was included in the model as a maximum regulated flow constraint of 30,000 ML/d at the Gundagai Gauge for the original Basin Plan scenarios.

NSW is currently assessing the feasibility of raising the Mundarlo Bridge and overcoming the associated inundation issues on adjacent land. For this study the constraint was relaxed to 50,000 ML/d, on the assumption that it can be overcome through flood mitigation measures.

A.3.2. Regulated flow rates at Balranald (Figure 3, location 6)

The Murrumbidgee River channel capacity between Redbank Weir and Balranald is generally between 8,000 and 12,000 ML/d (Page et al. 2005). When flows start to go overbank onto the floodplain around Chapton's Cutting, and in the areas around Redbank and Balranald, significant evaporation and seepage losses occur. Moreover, before flows higher than ~9,000 ML/d can be delivered to the Murray, the Lower Murrumbidgee wetlands must first be saturated. Therefore, the demands at Balranald targeting downstream demands in the Murray were limited to 9,000 ML/d in the original Basin Plan modelling, to ensure efficient delivery of environmental flows to the Murray.

However, targeting a higher flow rate at Balrandald would lead to significant increase in flows to the Lowbidgee system which could increase environmental benefits in the Lower Murrumbidgee system and contribute to the increased chances of success in achieving higher flow targets of the River Murray key ecological sites. Therefore for this study, the demand at Balranald was raised to 13,000 ML/d in an effort to get more water through the Lower Murrumbidgee wetlands and into the River Murray.

A.4. Goulburn River System

The physical and operational constraints in the Goulburn system that were relaxed in the modelling are:

- channel capacity between Eildon and Goulburn Weir
- regulated flow rates at McCoys Bridge.

A.4.1. Channel capacity constraints between Eildon and Goulburn Weir (Figure 3, location 7)

In general, Goulburn–Murray Water will undertake regulated deliveries up to the minor flood level. Though some nuisance flooding occurs at flows below the official minor flood level classification (e.g. pumps temporarily inundated), this can be managed with appropriate consultation and communication protocols (pers. comm. Mark Bailey (GMW), 1 June 2012).

To avoid risk of flooding private land, the releases from Eildon are managed so as to keep flows in the reach downstream of Eildon below 12,000 ML/d. However, releases of 15,000 ML/d have been made in the past for hydro-electricity generation. At a flow of 18,000 ML/d, flooding occurs at Trawool (pers. comm. Graeme Turner (DSE), 1 June 2012). The minor flow level downstream of Eildon according to the classification of the Bureau of Meteorology is 3.0 m (BOM 2012), which corresponds to a flow of 15,000 ML/d.

The monthly Goulburn Simulation Model (GSM) model includes constraints on the releases from Eildon in order to avoid flooding of areas around Trawool and Seymour. The release constraints in the original Basin Plan modelling were:

- The sum of the release and inflows between Eildon and Seymour cannot exceed 365 GL/Month (based on 12,000 ML/d)
- If there are releases for power generation or pre-releases, then the sum of the release and inflows between Eildon and Trawool cannot exceed 547 GL/month (18,000 ML/d).

For the relaxed constraints scenarios, the constraint on the release from Eildon was relaxed to 15,000 ML/d at Seymour (i.e. 456 GL/month).

The flood constraints were implemented in the model as a *monthly* flow volume and thus may be less constraining than in reality—as flooding may occur only for few days in a month, while the model does not reach the constraint unless average flow for all days of the month was greater than capacity constraint.

A.4.2. Regulated flow rates at McCoys Bridge (Figure 3, location 8)

Minor flood levels according to the classification of the Bureau of Meteorology (BOM 2012) are:

• Goulburn River @ Shepparton	9.5 m (RL)	26,062 ML/d [rating table 46.06]
• Goulburn River @ McCoy Bridge	9.0 m (RL)	28,333 ML/d [rating table 29.00].

Given that there are few tributaries downstream of Shepparton, the maximum regulated flow rate in the Goulburn River downstream of Shepparton is considered approximately 26,000 ML/d (pers. comm. Mark Bailey (GMW), 1 June 2012).

The GSM model does not include any channel capacity constraint in the Lower Goulburn, as the channel capacity constraint in the reach from Eildon to Goulburn Weir (as described above) reduces the likelihood that releases from Eildon would result in flows at Shepparton above the minor flood level of 26,062 ML/d.

However, in the modelling for the proposed Basin Plan (MDBA 2012b) a limit of 20,000 ML/d was used in the development of Murray demands at McCoy's Bridge. This constraint was used to ensure efficient delivery of flow to the Murray (avoiding floodplain losses, when flows would go overbank). This constraint has been relaxed to 40,000 ML/d, which is consistent with the in-valley targets for the Lower Goulburn Floodplain (DSE 2011; MDBA 2012b). This higher rate for delivery of flow to the Murray would be anticipated to provide environmental benefits for both Lower Goulburn floodplain as well as increase the likelihood of achieving higher flow targets for the Murray key ecological sites.

While the higher flow levels allowed in the constraints relaxed modelling is consistent with existing in-valley targets (DSE 2011), the extent to which they can be delivered without causing flooding in the area around Shepparton requires further investigation.

A.4.3. Feasibility and benefits of relaxing constraints

As discussed in Section 2, the feasibility and desirability of relaxing any of the constraints listed above needs further investigation and assessment. These would be technically complex projects which would require extensive landholder and key stakeholder involvement. At the time of writing this report the Constraints Management Strategy in the altered Basin Plan is anticipated to provide the framework for any further investigations although many of the constraints listed above have also been investigated by relevant States and/or water agencies.

Appendix B. Results for Murrumbidgee and Goulburn

The results of the BP-2800-RC and BP-3200-RC scenario for the Goulburn and Murrumbidgee systems are presented in this appendix. The Hydrological Modelling Report (MDBA 2012b) contains a full description of many of the data analysis concepts contained in the Basin Plan Modelling program, and the results are presented here in summary form only.

B.1. Murrumbidgee River System

The BP-2800-RC and BP-3200-RC scenarios were completed by relaxing the Gundagai constraint and regulated flow at Balranald as described in Section 2 and Appendix A. Environmental demands were adjusted according to methods described in Section 3. The changed number of events included in the demand series for each flow indicator is summarised in Table 2 in the main body of the report.

B.1.1. Environmental results

Table B.1 summaries the Murrumbidgee flow indicator results for all four Basin Plan scenarios. More detailed environmental indicator results are presented in Table B.2 to Table B.6, and are described below. Any changes to the environmental indicator results are a result of both the relaxation of the Gundagai constraint and the increase to the maximum flow rate at Balranald. However, as the effect of increasing the Gundagai constraint alone was marginal (see Appendix section B.1.2), the changes in flow described here are mostly due to the changes made to the environmental demand timeseries (Table 2).

For completeness, and to maintain consistency with the Hydrologic Modelling Report (MDBA 2012b), the length of the maximum dry period for each flow indicator is listed in Table B.7. Reducing the length of these dry periods was not directly targeted with the environmental watering strategy represented in the modelling, thus these results may underestimate the benefits that could be achieved with the Basin Plan.

Mid-Murrumbidgee Wetlands

Five flow indicators were developed to represent overbank flows into the mid-Murrumbidgee Wetlands, which are fully detailed in MDBA (2012b). For four of the five indicators corresponding environmental demand timeseries were included in the model. No demands were included for the 26,850 ML/d for 45 days indicator for consistency, as this indicator was developed after completion of the BP-2800 and BP-3200 scenarios.

The environmental indicator results for the mid-Murrumbidgee wetlands are presented in Table B.2 (BP-2800-RC) and Table B.3 (BP-3200-RC). Full results for the original BP-2800 and BP-3200 scenarios are presented in Section 5.9.7.2 of MDBA (2012b), with which the results presented here are compared. Table B.1 provides a summary for comparative purposes.

The three flow indicators that were met under the BP-2800 scenario (26,850 ML/d, 34,650 ML/d, 63,250 ML/d) were also met under the BP-2800-RC scenario, although there have been some relatively minor changes to the frequency of successful events. A number of events included in the Lower Murrumbidgee Floodplain timeseries for the BP-2800 scenario contributed to meeting the mid-Murrumbidgee Wetlands targets. As the number of Lower Murrumbidgee events was reduced in the BP-2800-RC scenario, the mid-Murrumbidgee results were impacted as a result, with the 34,650 ML/d event frequency declining by 1% and the 63,250 ML/d event frequency declining by 2%. Nevertheless, those impacted indicators are still within the target range and are considered successfully met.

Table B.1: Proportion of years containing a successful environmental event for the key hydrologic indicator sites on the Murrumbidgee River.

Hydrologic Indicator site	Flow indicator	Target: high to low uncertainty	Without develop-ment	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Mid-Murrumbidgee Wetlands	26,850 ML/d for 45 days	20 – 25%	28%	11%	14%	11%	17%	15%
	26,850 ML/d for 5 days	50 – 60%	67%	46%	59%	60%	62%	61%
	34,650 ML/d for 5 days	35 – 40%	57%	29%	40%	39%	44%	43%
	44,000 ML/d for 3 days	30 – 35%	44%	22%	28%	29%	29%	30%
	63,250 ML/d for 3 days	11 – 15%	21%	11%	13%	11%	11%	11%
Lower Murrumbidgee Floodplain	175,000 ML over 3 mths	70 - 75%	94%	68%	92%	91%	94%	93%
	270,000 ML over 3 mths	60 – 70%	92%	57%	85%	85%	89%	86%
	400,000 ML over 4 mths	55 – 60%	92%	52%	82%	82%	86%	83%
	800,000 ML over 4 mths	40 – 50%	78%	39%	56%	57%	67%	61%
	1,700,000 ML over 5 mths	20 – 25%	56%	18%	30%	31%	32%	34%
	2,700,000 ML over 10 mths	10 – 15%	44%	9%	17%	16%	19%	19%

🟩 Low uncertainty frequency or better
🟢 Low uncertainty to high uncertainty frequency range
🟨 Below high uncertainty frequency; improvement relative to baseline
⬜ No environmental demands specified in model

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Three of the four indicators in which environmental demands were specified were successfully met in both the BP-3200 and BP-3200-RC scenarios, these being the indicators for 26,850 ML/d for 5 days, 34,650 ML/d for 5 days and 63,250 ML/d for 3 days. Under the BP-3200-RC scenario, the 44,000 ML/d for 3 day indicator achieved the high uncertainty target for the first time.

Lower Murrumbidgee Floodplain

Six flow indicators were developed to represent overbank flows into the Lower Murrumbidgee Floodplain, and are fully detailed in MDBA 2012b. The targets for the Lower Murrumbidgee comprise a certain percentage of years where a total specified volume of water is delivered to the floodplain, represented by comparing the requirements to the flows at Maude Weir gauge once a Lower Murrumbidgee demand timeseries has been added to the model.

The environmental indicator results for the Lower Murrumbidgee Floodplain are presented in Table B.4 (BP-2800-RC) and Table B.5 (BP-3200-RC) and compared to the results presented in Section 5.9.7.2 of MDBA (2012b). The proportion of years containing a successful event in the original BP-2800 and BP-3200 scenarios is far higher than the target range for this indicator site. This over-achievement led to the decision to remove several events from the demand timeseries, and instead allow that water to be available for additional events in the Murray system, as detailed in Section 3.

As a result, the volumes of environmental water requested for the Lower Murrumbidgee has remained effectively unchanged between the relaxed constraints scenarios and the BP-2800 and BP-3200 scenarios. Instead, the pattern of this demand has been altered in the relaxed constraints scenario to maximise the contribution of Murrumbidgee environmental water to high-flow events for the Hattah and Chowilla sites. This is consistent with the southern connected system watering strategy represented in the modelling framework through the Environmental Event Selection Tool, designed to increase the efficiency of environmental water use.

Consequently, given that the Lower Murrumbidgee Floodplain environmental indicators are based on total volume of flow only, and the requested volumes of environmental water have remained effectively unchanged, the proportion of years with a successful event has been only marginally affected in the relaxed constraint scenarios, and all of the results are within the target range.

Balranald freshes

Three flow indicators were developed to represent freshes requirements at Balranald, which were included as a component of the Balranald demand timeseries added to the model. Full details of these requirements are detailed in MDBA 2012b and comprise a consistent level of flow for a prescribed numbers of days within a certain season.

The environmental indicator results for the Balranald Freshes are presented in Table B.6. The targets for all rules are met in all scenarios; with marginal changes in the proportion of successful years in the relaxed constraints scenarios, because of the reduction in Lower Murrumbidgee Floodplain events as described above. All three fresh targets are considered successfully met, as per the BP-2800 and BP-3200 scenarios.

Table B.2: Achievement of Mid-Murrumbidgee Wetlands flow indicators for without development, baseline, BP-2800 and BP-2800-RC scenarios.

Flow Indicator			Without development	Baseline	BP-2800*		BP-2800-RC*	
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Narrandera)		Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
1	26,850 ML/Day for a total duration of 45 days between Jul & Nov	20 - 25 %	28%	11%	16	14%	13	11%
2	26,850 ML/Day for 5 consecutive days between Jun & Nov	50 - 60 %	67%	46%	67	59%	68	60%
3	34,650 ML/Day for 5 consecutive days between Jun & Nov	35 - 40 %	57%	29%	46	40%	44	39%
4	44,000 ML/Day for 3 consecutive days between Jun & Nov	30 - 35 %	44%	22%	32	28%	33	29%
5	63,250 ML/Day for 3 consecutive days between Jun & Nov	11 - 15 %	21%	11%	15	13%	12	11%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Table B.3: Achievement of Mid-Murrumbidgee Wetlands flow indicators for without development, baseline, BP-3200 and BP-3200-RC scenarios.

			Without development	Baseline	BP-3200*		BP-3200-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Narrandera)		Target proportion of years with a successful event - high to low uncertainty						
1	26,850 ML/Day for a total duration of 45 days between Jul & Nov	20 - 25 %	28%	11%	19	17%	17	15%
2	26,850 ML/Day for 5 consecutive days between Jun & Nov	50 - 60 %	67%	46%	71	62%	70	61%
3	34,650 ML/Day for 5 consecutive days between Jun & Nov	35 - 40 %	57%	29%	50	44%	49	43%
4	44,000 ML/Day for 3 consecutive days between Jun & Nov	30 - 35 %	44%	22%	33	29%	34	30%
5	63,250 ML/Day for 3 consecutive days between Jun & Nov	11 - 15 %	21%	11%	12	11%	13	11%

[*] Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

Table B.4: Achievement of Lower Murrumbidgee Floodplain flow indicators for without development, baseline, BP-2800 and BP-2800-RC scenarios.

			Without development	Baseline	BP-2800*		BP-2800-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Maude Weir)		Target proportion of years with a successful event - high to low uncertainty						
1	Total volume of 175 GL (flow > 5000 ML/day) between Jul & Sep	70 - 75 %	94%	68%	105	92%	104	91%
2	Total volume of 270 GL (flow > 5000 ML/day) between Jul & Sep	60 - 70 %	92%	57%	97	85%	97	85%
3	Total volume of 400 GL (flow > 5000 ML/day) between Jul & Oct	55 - 60 %	92%	52%	93	82%	94	82%
4	Total volume of 800 GL (flow > 5000 ML/day) between Jul & Oct	40 - 50 %	78%	39%	64	56%	65	57%
5	Total volume of 1700 GL (flow > 5000 ML/day) between Jul & Nov	20 - 25 %	56%	18%	34	30%	35	31%
6	Total volume of 2700 GL (flow > 5000 ML/day) between May & Feb	10 - 15 %	44%	9%	19	17%	18	16%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events ‘ordered and delivered within 10%’).

Table B.5: Achievement of Lower Murrumbidgee Floodplain flow indicators for without development, baseline, BP-3200 and BP-3200-RC scenarios.

Flow Indicator			Without development	Baseline	BP-3200*		BP-3200-RC*	
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Maude Weir)		Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
1	Total volume of 175 GL (flow > 5000 ML/day) between Jul & Sep	70 - 75 %	94%	68%	107	94%	106	93%
2	Total volume of 270 GL (flow > 5000 ML/day) between Jul & Sep	60 - 70 %	92%	57%	102	89%	98	86%
3	Total volume of 400 GL (flow > 5000 ML/day) between Jul & Oct	55 - 60 %	92%	52%	98	86%	95	83%
4	Total volume of 800 GL (flow > 5000 ML/day) between Jul & Oct	40 - 50 %	78%	39%	76	67%	70	61%
5	Total volume of 1700 GL (flow > 5000 ML/day) between Jul & Nov	20 - 25 %	56%	18%	37	32%	39	34%
6	Total volume of 2700 GL (flow > 5000 ML/day) between May & Feb	10 - 15 %	44%	9%	22	19%	22	19%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Table B.6: Achievement of Balranald fresh flow indicators for without development, baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.

			Without development	Baseline	BP-2800*		BP-2800-RC*		BP-3200*		BP-3200-RC*	
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event within 10%	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Proportion of years with a successful event
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Balranald Weir)		Target proportion of years with a successful event - high to low uncertainty										
1	1100 ML/Day for 25 consecutive days between Dec & May	58 - 77 %	96%	32%	78	68%	75	66%	76	67%	80	70%
2	4500 ML/Day for 20 consecutive days between Oct & Dec	54 - 72 %	90%	35%	79	69%	81	71%	84	74%	81	71%
3	3100 ML/Day for 30 consecutive days between Oct & Mar	55 - 73 %	91%	29%	78	68%	81	71%	86	75%	85	75%

* Successful environmental events in the Basin Plan scenarios include events that are within 10% of the flow indicator threshold and duration, for those events specifically ordered in the demand timeseries (see Appendix C and MDBA 2012b for further description of events 'ordered and delivered within 10%').

Table B.7: Overview of maximum dry periods between flow indicator events for Murrumbidgee system.

Hydrologic Indicator site	Flow indicator	Maximum dry period in years between successful flow indicator events					
		Without develop-ment	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Mid-Murrumbidgee Wetlands	26,850 ML/d for 45 days (Jul-Nov)	4	9	11	21	9	17
	26,850 ML/d for 5 days (Jun-Nov)	5	13	13	11	10	9
	34,650 ML/d for 5 days (Jun-Nov)	9	16	14	11	14	9
	44,000 ML/d for 3 days (Jun-Nov)	16	33	33	14	34	14
	63,250 ML/d for 3 days (Jun-Nov)	11	21	19	34	17	34
Lower Murrumbidgee Floodplain	175,000 ML over 3 mths (Jul-Sep)	2	5	3	3	3	3
	270,000 ML over 3 mths(Jul-Sep)	3	9	4	3	3	3
	400,000 ML over 4 mths (Jul-Oct)	2	9	4	4	4	4
	800,000 ML over 4 mths (Jul-Oct)	4	13	9	9	5	5
	1,700,000 ML over 5 mths (Jul-Nov)	5	16	13	13	13	13
	2,700,000 ML over 10 mths (May-Feb)	9	21	16	16	16	16
Balranald Freshes	1,100 ML/d for 25 days (Dec-May)	2	14	5	8	6	4
	4,500 ML/d for 20 days (Oct-Dec)	3	13	5	5	4	5
	3,100 ML/d for 30 days (Oct-Mar)	3	13	5	5	4	4

Achievement of baseflows

Environmental demand series to address baseflows have been included as a component of the demand at Balranald. Table B.8 outlines the results for the baseflow requirements at various sites in the Murrumbidgee, measured as a volumetric shortfall (i.e. the mean annual volume of additional water required at each site to meet the baseflow demand series). The results show that the relaxation of the Gundagai constraint and increasing the volume of flows at Balranald only has a marginal improvement in baseflow indicators. This is consistent with the expectation that altering the constraints would have the greatest impact at the high-end of the flow regime.

Table B.8: The shortfall in meeting baseflow assessment demand series in the Murrumbidgee under the modelled scenarios.

Site	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
410073 – Tumut@Oddy’s Bridge	35.8	35.6	33.5	31.9
410131 – Murrumbidgee@Burrinjuck Inflows	0.6	0.6	0.6	0.6
410001 – Murrumbidgee@Wagga Wagga	0.9	0.8	1.2	0.9
410021 – Murrumbidgee@Darlington Point	4.0	4.3	3.8	3.9
410130 – Murrumbidgee@Balranald Weir	26.7	22.6	20.3	17.0

B.1.2. Hydrological results

Table B.9 presents a summary of the Murrumbidgee water balance showing that the reductions in gross diversions in the relaxed constraints scenarios were consistent with the targeted diversion reductions and the original Basin Plan scenarios.

Table B.9: Water balance for the Murrumbidgee region (GL/y)

	Without development	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Inflow	4236	4742	4741	4741	4741	4741
Diversion[1]	0	2107	1514	1514	1393	1393
Loss[2]	1388	1090	1222	1213	1250	1251
Outflow[3]	2848	1545	2005	2014	2098	2097

[1] Loss includes unattributed loss, change in storage and Forest Ck outflow, also includes irrigation area returns

[2] Gross diversions. Based on feedback from the public consultation process, Murrumbidgee diversions were changed to net diversions for Baseline Diversion Limit (BDL) determination subsequent to the modelling effort described in MDBA (2012b).

[3] Outflow to Murray (Balranald+Darlot) without TLM.

The BP-2800-RC scenario shows an increase in annual average outflow to the River Murray (Balranald plus Darlot flow) of 9 GL/y as a long-term average. No significant change is seen in the annual average outflows between the BP-3200 and BP-3200-RC scenarios. However, both relaxed constraints scenarios showed an increase in flows at Balranald above 9,000 ML/d, i.e. a 22.9 GL/y and 53.3 GL/y increase for the BP-2800-RC and BP-3200-RC scenarios respectively. In the BP-2800-RC scenario this increase occurred in the flow range between 9,000 to 13,000 ML/d, but was to some extent at the expense of spills from storage decreasing flows in the range of 15,000 to 20,000 ML/d. This may explain the reduction in annual average loss and increase in annual average outflow in this scenario (Table B.9).

These changes in the flow regime (and associated environmental outcomes) were mainly due to the increase of the Balranald maximum flow limit of 9,000 to 13,000 ML/d. The relaxed constraint scenarios showed that the orders at Gundagai were over 30,000 ML/d for less than 1% of the time. This means that relaxation of the Gundagai release constraint only affected the results for very small part of the simulated period. This is related to the fact that releases in the model were still constraint by the channel capacity constraints in the Tumut River.

Separate work carried out on the Murrumbidgee model has shown that the efficiency of delivering higher flows to the Mid-Murrumbidgee wetlands could be increased further, if the channel capacity of the Tumut River and associated release from Blowering Dam were relaxed in addition to the Gundagai constraint. The Tumut constraint is in place to limit bank erosion and inundation of private property. Moreover, environmental releases from Blowering would require prior arrangement with Snowy Hydro Limited. Relaxation of these constraints would be much more difficult to achieve in practise and was therefore not included in the modelling.

To ensure that the modelling scenario was consistent with the targeted water recovery volume, a key part of the modelling process was to check the pattern of both the reduction in diversions and storage levels, relative to baseline conditions. This step was necessary to ensure that the process of developing environmental demands using an environmental account outside of the models did not impact on the long-term reliability of other water users, or result in a reduction in diversions that exceeded the water recovery target.

Annual diversions and end-of-system flows for the Murrumbidgee are presented in Figure B.1 and Figure B.2, respectively. These highlight the consistent pattern of diversions and water availability levels resulting from the modelled scenarios, and the increase in end-of-system flows.

The BP-2800-RC scenario showed a long-term average change in total storage volume (Burrinjuck plus Blowering) of -0.5 GL/y, when compared to baseline long-term average storage volumes. This equates to a less than 0.1% difference. Similarly, for the BP-3200-RC scenario, Burrinjuck plus Blowering storage volumes are 2.2 GL/y higher (0.1%), when compared to baseline. Storage volume behaviour is presented in Figure B.3, and all plotted scenarios closely match baseline conditions storage behaviour.

Figure B.1: Murrumbidgee annual diversions for the baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.

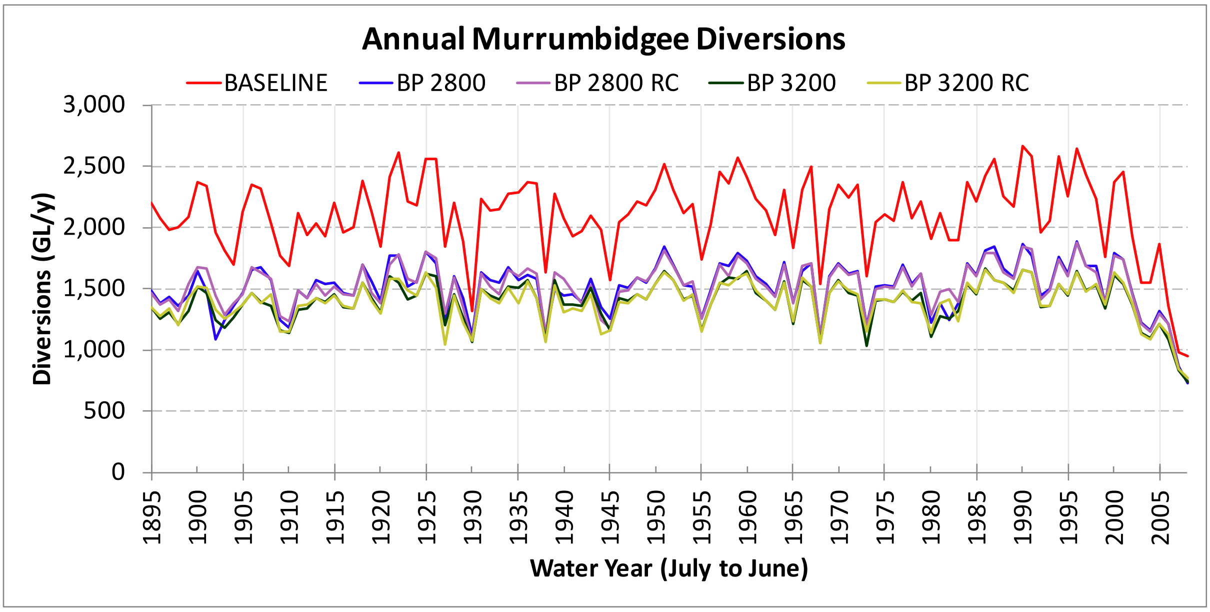


Figure B.2: Annual end of system flows (Balranald plus Darlot) from the Murrumbidgee, for the without development, baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.

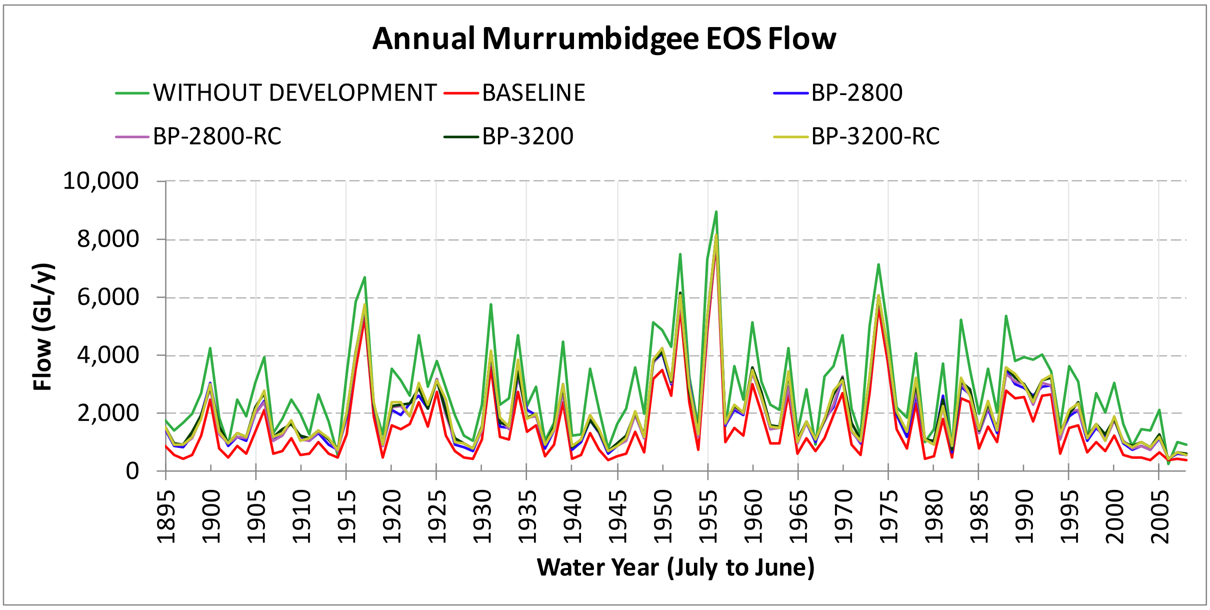
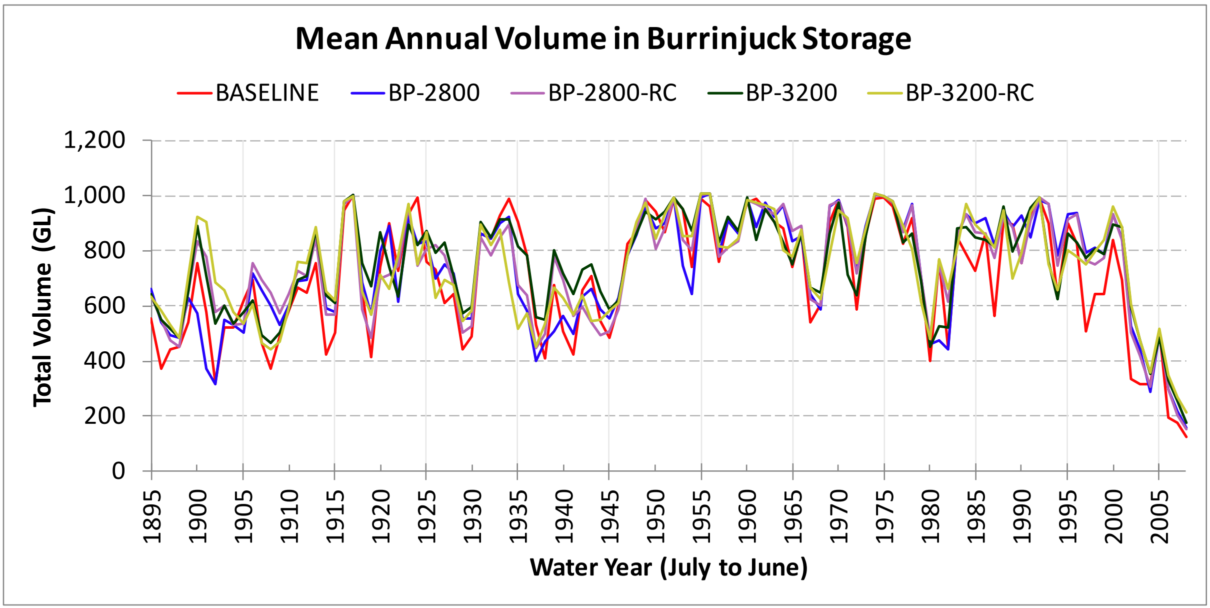
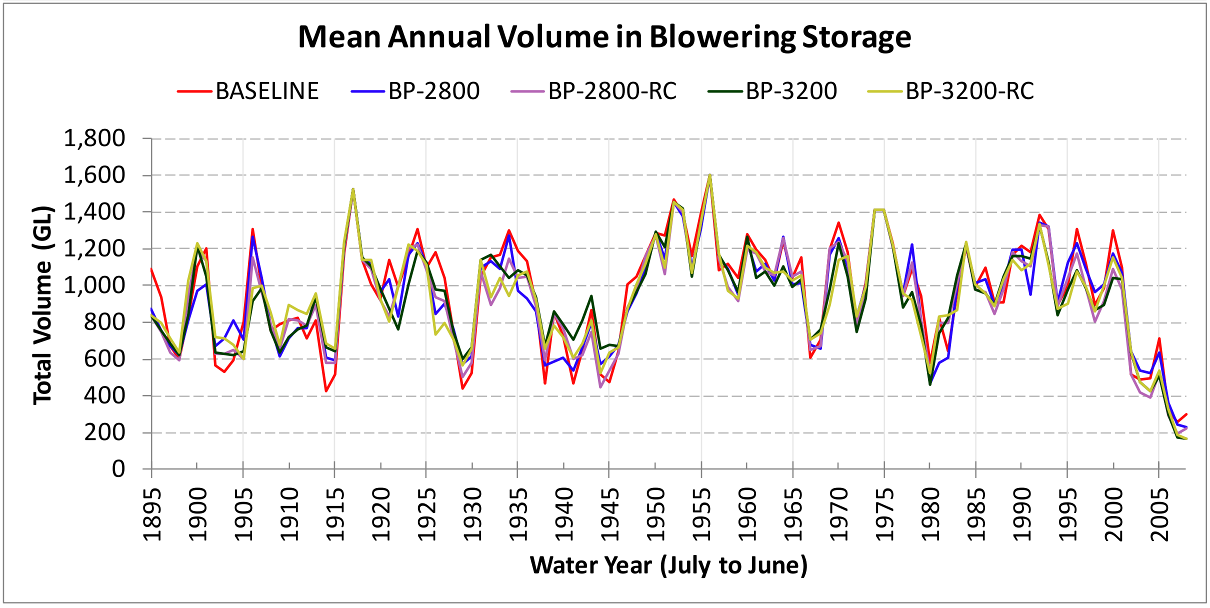


Figure B.3: Average annual volume in the two main Murrumbidgee storages (Burrinjuck and Blowering Dam) for the baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.





B.2. Goulburn River system

The difference between the BP-2800 and BP-3200 scenarios and the relaxed constraints scenarios described in this report is the relaxation of some of the constraints, as described in section 3 and Appendix A. In addition, the McCoys Bridge demands were adjusted to target higher achievement for high-flow events in the lower Murray system, particularly at the Hattah and Chowilla indicator sites.

B.2.1. Environmental results

Lower Goulburn floodplain

The whole-of-Basin modelling scenarios for the proposed Basin Plan were based on an initial set of flow targets for the Lower Goulburn floodplain. Shortly before the release of the proposed draft Basin Plan and after the conclusion of the MDBA's Basin-wide modelling of a 2800 GL/y reduction in diversions scenario, an updated set of environmental water requirements was developed by MDBA based on assessments published by Victoria (DSE 2011). The MDBA's assessment was that this updated information represented the best available science and decided to adopt the new work as flow indicators for the Lower Goulburn floodplain. To provide an assessment of the capacity for the Basin Plan to deliver on these environmental water requirements an 'in-valley' modelling scenario was undertaken (for the Goulburn only) and was presented in the Hydrologic Modelling report (MDBA 2012b).

This means that while the Basin Plan whole-of-Basin modelling had the correct volume of water being recovered from the Goulburn the pattern of river flows was not aligned to delivery of desirable in-valley outcomes as specified by the revised set of flow indicators for the Lower Goulburn floodplain. Given that the testing of constraints requires the method to remain consistent with the original modelling scenarios, this discrepancy was maintained. As such, the constraints relaxed scenarios were still based on the initial targets for consistency with the original BP-2800 and BP-3200 scenarios. Therefore demands included events of 25,000 ML/d, 30,000 ML/d and 45,000 ML/d.

The updated flow targets were based on flow events of 25,000 ML/d and 40,000 ML/d and do not include 30,000 ML/d or 45,000 ML/d events (MDBA 2012b). In the Hydrological Modelling report it was demonstrated with an in-valley scenario that the new targets could largely be met with the proposed level of reduction for in-valley needs and could therefore be fully met with the combination of in-valley and downstream contribution water recovery. No further assessment has been made for the Lower Goulburn Floodplain targets here; however, relaxation of flood constraints in the Goulburn could also assist in improving the achievement of targets for the Lower Goulburn floodplain.

Baseflows

The adjustment of the demands mainly involved a better timing of high-flow events with the demands for Hattah and Chowilla. These adjustments have had only small impacts on the achievement of the baseflow targets (Table B.10). For sites upstream of Goulburn Weir there was some improvement, while there was some small increase in shortfalls in the lower part of the Goulburn.

Table B.10: The shortfall, or required additional mean annual volume (in GL/y), at each site to meet the baseflow demand series for baseline and In-valley SDL scenarios.

Site[1]	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
405203 – Goulburn@D/S Eildon	186.0	66.5	55.5	50.5	42.6
405201 – Goulburn@Trawool	5.7	1.9	2.0	0.9	1.1
FSR 40512 – Goulburn@U/S Goulburn Weir	1.5	0.7	0.6	0.0	0.0
405253 – Goulburn@D/S Goulburn Weir	156.7	36.1	39.5	28.6	32.1
405272 – Goulburn@Mooroopna	102.1	19.1	21.5	14.1	16.1
405276 – Goulburn@Loch Gary	50.6	2.5	3.6	0.3	0.7
405232 – Goulburn@D/S McCoy's Bridge	48.4	2.4	3.4	0.3	0.7
FSR 40501 – Goulburn inflows into Murray	48.5	2.4	3.4	0.3	0.7

[1] No baseflow demand was included for the sites marked in grey.

B.2.2. Hydrological results

Both relaxed constraint scenarios showed a higher frequency of flows at McCoys Bridge in the 20,000 ML/d to 40,000 ML/d flow range. For the BP-2800-RC scenario the increase of flow over 20,000 ML/d was 42.9 GL/y, of which 38.4 GL/y coincided with the timing of Hattah and Chowilla demands at the end of the Goulburn system. The remaining additional high flows would be contributing to in-valley high-flow events. For the BP-3200-RC scenario the increase in flows over 20,000 ML/d was 55.3 GL/y, of which 47.2 GL/y coincided with Hattah and Chowilla demands.

The constraint relaxed scenarios show similar reduction in diversions as modelled in the equivalent proposed Basin Plan scenarios (Table B.11). Also the annual average losses and outflows are almost the same between the two scenarios (original BP scenario and its equivalent with constraint relaxed). The difference between the scenarios is in the demand and flow patterns.

Table B.11: Water balance for the Goulburn-Broken region (GL/y)

	Without development	Baseline	BP-2800	BP-2800-RC	BP-3200	BP-3200-RC
Inflow	3378	3379	3379	3379	3379	3379
Diversion	0	1579	1120	1120	1027	1026
Loss[1]	10	153	155	154	153	153
Outflow[2]	3368	1647	2104	2105	2199	2200

[1] Loss includes unattributed loss and change in storage

[2] Outflow at McCoy's Bridge

The diversion and end of system flow patterns for the Basin Plan scenarios are similar to the baseline pattern, and differences between the original Basin Plan scenario and its equivalent constraint relaxed scenario are minimal (Figure B.4 and Figure B.5).

Figure B.4: Total annual diversions from the Goulburn-Broken system for baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.

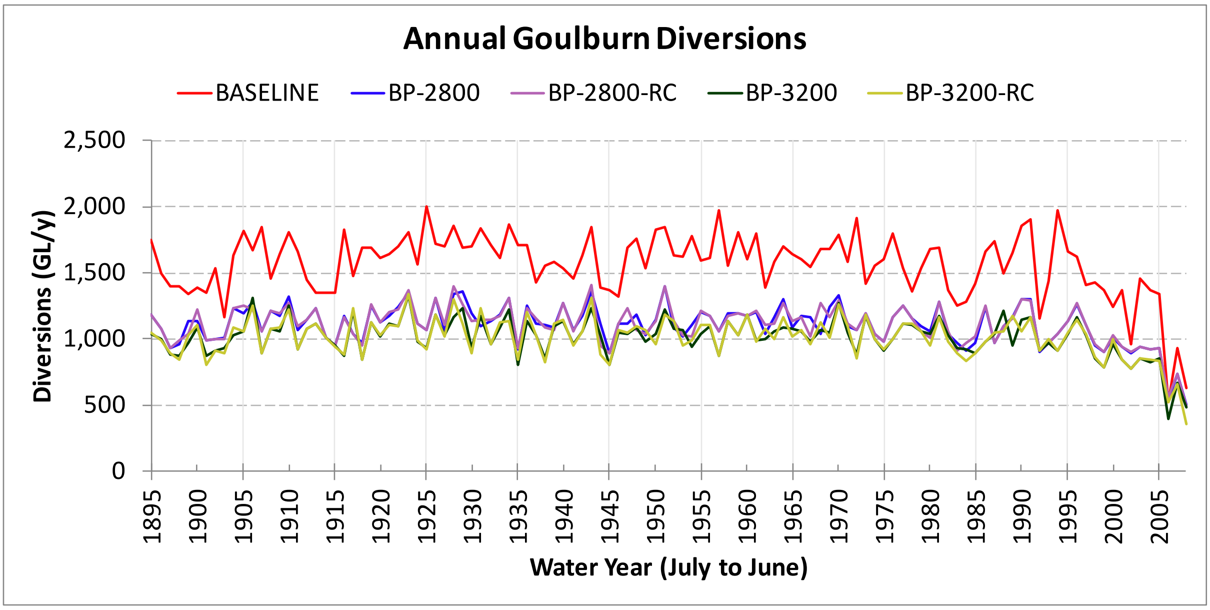
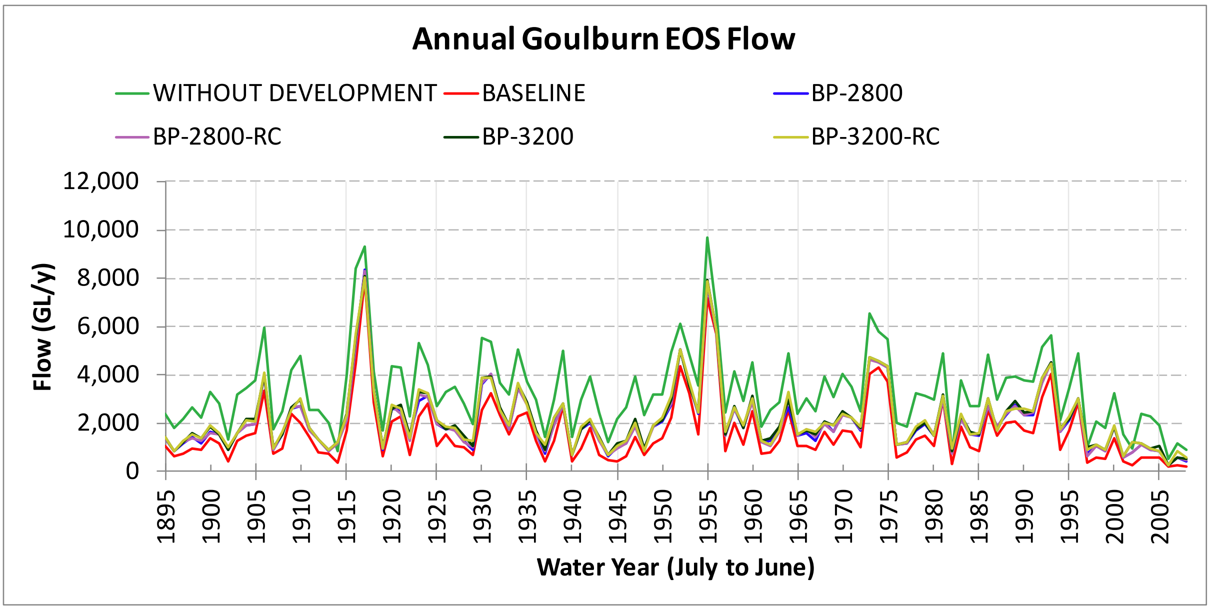
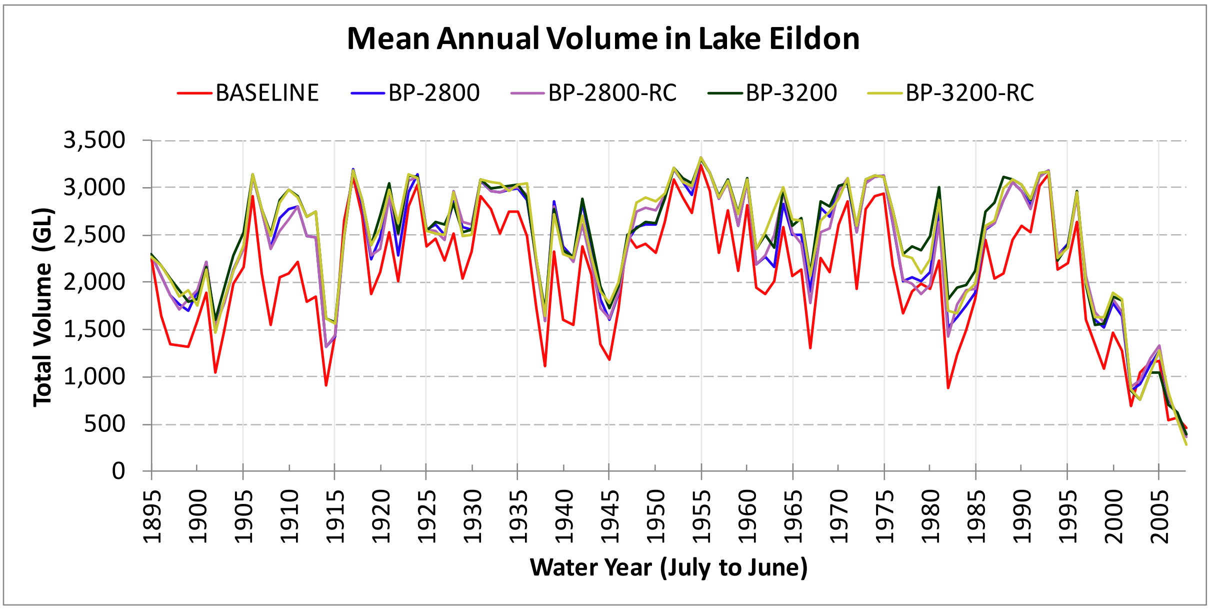


Figure B.5: Annual end of system flows from the Goulburn-Broken system (at McCoy's Bridge) for the without development, baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.



All Basin Plan scenarios show higher storage volumes in Lake Eildon compared to baseline (Figure B.6). This is because not all environmental water is used, and hence is carried over. The differences between the BP-2800 and BP-2800-RC and the BP-3200 and BP-3200-RC are relatively small.

Figure B.6: Average annual volume in storage in Lake Eildon for the baseline, BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC scenarios.



Appendix C. Flow indicator achievement tables

In the 'Hydrologic modelling report to inform the proposed Basin Plan' (MDBA 2012b) environmental results were presented based on an 'event-by-event' analysis of the results. In this appendix the results of the relaxed constraints scenarios are presented in the same format. A summary is provided below of the different categories of events being reported in the tables which follow in the rest of this appendix. More detailed information on the interpretation of these categories is provided in Section 5.1 of the Hydrologic Modelling report (MDBA, 2012b).

The results have been categorised according to different types of events, and an aggregate of successful environmental events is used as an overall performance measure. The event types, other than those already met under baseline conditions are:

1. Ordered and fully delivered

These events represent the targeted delivery of water to the specific indicator site. They fully achieve the flow criteria and are considered successful.

2. Ordered and delivered within 10%

These events also represent the targeted delivery of water to the specific indicator site. It represents ordered flow events that achieve flow criteria within 10% of flow magnitude and duration where there was sufficient water in the account to implement the event. The allowance for 10% acknowledges that in operational reality model limitations such as timing can be overcome.

3. Other successful events

These events are not requested in the demand timeseries for the specific indicator site but they fully achieve the flow criteria. These events have occurred as a result of events targeted at other indicator sites, additional spills from dams and/or reduced take of water from flow events.

4. Baseline events lost

These are events that occurred in the baseline timeseries but do not occur in the respective Basin Plan scenario. This can be due to changed storage behaviour or by an enhancement of multiple smaller events into a single larger event (most relevant to in-stream freshes). These events are subtracted to recognise their loss from the model result timeseries.

5. Total additional to baseline

This is the sum of the previous 4 event types, and expresses the additional number of successful flow events compared to the baseline.

6. No. of additional years with events partially delivered

Partially delivered events are considered to have delivered some environmental benefits, these benefits are generally not the same as those associated with the specified flow indicator. These events are divided into two categories:

- Events that were requested in the demand timeseries but did *not* achieve the flow criteria within 10%. These events are considered to have fallen too far short of the parameters of a flow indicator to consider the event to be successful
- Events that were *not* requested through a demand timeseries for that site, yet they nearly achieved the flow criteria (within 10%). These events are representative of an altered flow regime but there is uncertainty to the extent to which they could be augmented to deliver a successful environmental event.

Table C.1: Flow indicator achievement for the Barmah–Millewa Forest under without development, baseline and BP-2800-RC scenarios.

			Without development	Baseline		BP-2800-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
	Flow Event - threshold, duration, season (as gauged on the River Murray at Yarrawonga Weir)	Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	87%	50%	57	27	0	13	-4	36	93	82%	3
2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	34	8	0	18	-1	25	59	52%	11
3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	34	8	0	11	-1	18	52	46%	8
4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33 - 40 %	53%	24%	27	10	0	5	-4	11	38	33%	5
5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25 - 30 %	39%	18%	20	0	0	0	-4	-4	16	14%	3
6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20 - 25 %	33%	14%	16	0	0	0	-4	-4	12	11%	5
7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	44%	11%	12	26	0	7	-1	32	44	39%	9

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events (Appendix C).

Table C.2: Flow indicator achievement for the Barmah–Millewa Forest under without development, baseline and BP-3200-RC scenarios.

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
	Flow Event - threshold, duration, season (as gauged on the River Murray at Yarrawonga Weir)	Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	12,500 ML/d for a total duration of 70 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	87%	50%	57	27	0	13	-4	36	93	82%	5
2	16,000 ML/d for a total duration of 98 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	34	8	0	21	0	29	63	55%	10
3	25,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Nov	40 - 50 %	66%	30%	34	8	0	11	0	19	53	46%	3
4	35,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	33 - 40 %	53%	24%	27	10	1	5	-3	13	40	35%	3
5	50,000 ML/d for a total duration of 21 days (with min duration of 7 consecutive days) between Jun & May	25 - 30 %	39%	18%	20	0	0	1	-3	-2	18	16%	1
6	60,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	20 - 25 %	33%	14%	16	0	0	0	-5	-5	11	10%	7
7	15,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	44%	11%	12	30	0	4	-1	33	45	39%	9

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful environmental events (Appendix C).

Table C.3: Flow indicator achievement for the Gunbower–Koondrook–Perricoota Forest under without development, baseline and BP-2800-RC scenarios.

			Without development	Baseline		BP-2800-RC							
Flow Indicator						Number of years with successful events							
	Flow Event - threshold, duration, season (as gauged on the River Murray at Torrumbarry Weir)	Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)	Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	86%	31%	35	23	11	7	0	41	76	67%	10
2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60 - 70 %	87%	34%	39	15	8	5	0	28	67	59%	10
3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33 - 50 %	60%	25%	28	3	3	7	0	13	41	36%	8
4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25 - 33 %	39%	11%	13	4	2	4	0	10	23	20%	9
5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	43%	7%	8	10	11	1	-1	21	29	25%	7

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.4: Flow indicator achievement for the Gunbower–Koondrook–Perricoota Forest under without development, baseline and BP-3200-RC scenarios.

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the River Murray at Torrumbarry Weir)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	16,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Nov	70 - 80 %	86%	31%	35	31	14	1	0	46	81	71%	12
2	20,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Nov	60 - 70 %	87%	34%	39	18	8	4	0	30	69	61%	11
3	30,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	33 - 50 %	60%	25%	28	4	3	8	0	15	43	38%	6
4	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & May	25 - 33 %	39%	11%	13	10	4	2	-1	15	28	25%	6
5	20,000 ML/d for a total duration of 150 days (with min duration of 7 consecutive days) between Jun & Dec	30%	43%	7%	8	18	10	1	0	29	37	32%	4

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.5: Flow indicator achievement for Hattah Lakes under without development, baseline and BP-2800-RC scenarios.

			Without development	Baseline		BP-2800-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
	Flow Event - threshold, duration, season (as gauged on the River Murray at Euston Weir)	Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40 - 50 %	67%	30%	34	8	1	8	0	17	51	45%	5
2	50,000 ML/d for a total duration of 60 days (with a min duration of 7 consecutive days) between Jun & Dec	30 - 40 %	47%	19%	22	5	5	4	0	14	36	32%	15
3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20 - 33 %	38%	11%	13	1	2	3	0	6	19	17%	7
4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20 - 30 %	33%	10%	11	1	2	1	0	4	15	13%	4
5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14 - 20 %	23%	8%	9	0	0	0	0	0	9	8%	4
6	150,000 ML/Day for 7 consecutive days between Jun & May	10 - 13 %	17%	5%	6	0	0	0	0	0	6	5%	2

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.6: Flow indicator achievement for Hattah Lakes under without development, baseline and BP-3200-RC scenarios.

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the River Murray at Euston Weir)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	40,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	40 - 50 %	67%	30%	34	7	2	9	0	18	52	46%	6
2	50,000 ML/d for a total duration of 60 days (with a min duration of 7 consecutive days) between Jun & Dec	30 - 40 %	47%	19%	22	7	3	8	0	18	40	35%	15
3	70,000 ML/d for a total duration of 42 days (with min duration of 7 consecutive days) between Jun & Dec	20 - 33 %	38%	11%	13	6	3	1	0	10	23	20%	6
4	85,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	20 - 30 %	33%	10%	11	0	5	1	0	6	17	15%	8
5	120,000 ML/d for a total duration of 14 days (with min duration of 7 consecutive days) between Jun & May	14 - 20 %	23%	8%	9	0	0	0	0	0	9	8%	3
6	150,000 ML/Day for 7 consecutive days between Jun & May	10 - 13 %	17%	5%	6	0	0	1	0	1	7	6%	2

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.7: Flow indicator achievement for Riverland–Chowilla Floodplain under without development, baseline and BP-2800-RC scenarios.

			Without development	Baseline		BP-2800-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the River Murray at SA Border)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	20,000 ML/d for 60 consecutive days between Aug & Dec	72 - 80 %	89%	43%	49	0	0	28	0	28	77	68%	3
2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50 - 70 %	80%	37%	42	8	8	8	0	24	66	58%	4
3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33 - 50 %	58%	22%	25	4	4	6	0	14	39	34%	8
4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25 - 33 %	41%	12%	14	5	5	5	0	15	29	25%	4
5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17 - 25 %	34%	10%	11	0	3	1	0	4	15	13%	6
6	100,000 ML/d for a total duration of 21 days between Jun & May	13 - 17 %	19%	6%	7	0	0	0	0	0	7	6%	4
7	125,000 ML/d for a total duration of 7 days between Jun & May	10 - 13 %	17%	4%	5	0	0	0	0	0	5	4%	0

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.8: Flow indicator achievement for Riverland–Chowilla Floodplain under without development, baseline and BP-3200-RC scenarios.

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the River Murray at SA Border)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	20,000 ML/d for 60 consecutive days between Aug & Dec	72 - 80 %	89%	43%	49	0	0	35	0	35	84	74%	3
2	40,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & Dec	50 - 70 %	80%	37%	42	10	5	8	0	23	65	57%	7
3	40,000 ML/d for a total duration of 90 days (with min duration of 7 consecutive days) between Jun & Dec	33 - 50 %	58%	22%	25	6	2	8	0	16	41	36%	9
4	60,000 ML/d for a total duration of 60 days (with min duration of 7 consecutive days) between Jun & Dec	25 - 33 %	41%	12%	14	9	4	2	0	15	29	25%	5
5	80,000 ML/d for a total duration of 30 days (with min duration of 7 consecutive days) between Jun & May	17 - 25 %	34%	10%	11	0	8	1	0	9	20	18%	7
6	100,000 ML/d for a total duration of 21 days between Jun & May	13 - 17 %	19%	6%	7	0	0	1	-1	0	7	6%	4
7	125,000 ML/d for a total duration of 7 days between Jun & May	10 - 13 %	17%	4%	5	0	0	0	-1	-1	4	4%	3

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.9: Flow indicator achievement for the Edward–Wakool River system under without development, baseline and BP-2800-RC scenarios. Note: these flow indicators have not been entered as demands in Basin Plan modelling scenarios, and consequently the results do not indicate the full extent of potential achievement under the proposed Basin Plan.

			Without development	Baseline		BP-2800-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
	Flow Event - threshold, duration, season (as gauged on the Edward River at Deniliquin)	Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	1,500 ML/Day for a total duration of 180 days (with a minimum duration of 1 consecutive day) between Jun & Mar	99 - 100 %	75%	96%	110	0	0	2	-3	-1	109	96%	3
2	5,000 ML/Day for a total duration of 60 days (with a minimum duration of 7 consecutive days) between Jun & Dec	60 - 70 %	82%	39%	44	0	0	26	0	26	70	61%	7
3	5,000 ML/Day for a total of 120 days (with a minimum duration of 7 consecutive days) between Jun & Dec	35 - 40 %	52%	22%	25	0	0	16	-1	15	40	35%	12
4	18,000 ML/Day for a total of 28 days (with a minimum duration of 5 consecutive days) between Jun & Dec	25 - 30 %	39%	15%	17	0	0	1	-1	0	17	15%	4
5	30,000 ML/Day for a total of 21 days (with a minimum duration of 6 consecutive days) between Jun & Dec	17 - 20 %	28%	12%	14	0	0	1	-3	-2	12	11%	3

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.10: Flow indicator achievement for the Edward–Wakool River system under without development, baseline and BP-3200-RC scenarios. Note: these flow indicators have not been entered as demands in Basin Plan modelling scenarios, and consequently the results do not indicate the full extent of potential achievement under the proposed Basin Plan.

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
	Flow Event - threshold, duration, season (as gauged on the Edward River at Deniliquin)	Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	1,500 ML/Day for a total duration of 180 days (with a minimum duration of 1 consecutive day) between Jun & Mar	99 - 100 %	75%	96%	110	0	0	1	-5	-4	106	93%	4
2	5,000 ML/Day for a total duration of 60 days (with a minimum duration of 7 consecutive days) between Jun & Dec	60 - 70 %	82%	39%	44	0	0	27	0	27	71	62%	5
3	5,000 ML/Day for a total of 120 days (with a minimum duration of 7 consecutive days) between Jun & Dec	35 - 40 %	52%	22%	25	0	0	19	0	19	44	39%	13
4	18,000 ML/Day for a total of 28 days (with a minimum duration of 5 consecutive days) between Jun & Dec	25 - 30 %	39%	15%	17	0	0	1	0	1	18	16%	3
5	30,000 ML/Day for a total of 21 days (with a minimum duration of 6 consecutive days) between Jun & Dec	17 - 20 %	28%	12%	14	0	0	1	-4	-3	11	10%	3

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.11: Flow indicator achievement for the Lower Darling River system under without development, baseline and BP-2800-RC scenarios. Note: these flow indicators have not been entered as demands in Basin Plan modelling scenarios, and consequently the results to not indicate the full extent of potential achievement under the proposed Basin Plan.

			Without development	Baseline		BP-2800-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the Darling River at Weir 32)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	20,000 ML/Day for 30 consecutive days between Jun & May	14 - 20 %	27%	10%	11	0	0	2	0	2	13	11%	6
2	25,000 ML/Day for 45 consecutive days between Jun & May	8 - 10 %	14%	8%	9	0	0	0	0	0	9	8%	0
3	45,000 ML/Day for 2 consecutive days between Jun & May	7 - 10 %	11%	8%	9	0	0	0	0	0	9	8%	1
4	7,000 ML/Day for 10 consecutive days between Jun & May	70 - 90 %	95%	51%	58	0	0	20	-10	10	68	60%	4
5	17,000 ML/Day for 18 consecutive days between Jun & May	20 - 40 %	49%	18%	21	0	0	8	0	8	29	25%	3

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.12: Flow indicator achievement for the Lower Darling River system under without development, baseline and BP-3200-RC scenarios. Note: these flow indicators have not been entered as demands in Basin Plan modelling scenarios, and consequently the results to not indicate the full extent of potential achievement under the proposed Basin Plan.

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the Darling River at Weir 32)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	20,000 ML/Day for 30 consecutive days between Jun & May	14 - 20 %	27%	10%	11	0	0	2	0	2	13	11%	6
2	25,000 ML/Day for 45 consecutive days between Jun & May	8 - 10 %	14%	8%	9	0	0	0	0	0	9	8%	0
3	45,000 ML/Day for 2 consecutive days between Jun & May	7 - 10 %	11%	8%	9	0	0	0	0	0	9	8%	1
4	7,000 ML/Day for 10 consecutive days between Jun & May	70 - 90 %	95%	51%	58	0	0	19	-13	6	64	56%	3
5	17,000 ML/Day for 18 consecutive days between Jun & May	20 - 40 %	49%	18%	21	0	0	9	0	9	30	26%	0

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.13: Flow indicator achievement of mid-Murrumbidgee Wetlands flow indicators under without development, baseline and BP-2800-RC

			Without development	Baseline		BP-2800-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Narrandera)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	26,850 ML/Day for a total duration of 45 days between Jul & Nov	20 - 25 %	28%	11%	13	0	0	1	-1	0	13	11%	11
2	26,850 ML/Day for 5 consecutive days between Jun & Nov	50 - 60 %	67%	46%	52	6	5	6	-1	16	68	60%	5
3	34,650 ML/Day for 5 consecutive days between Jun & Nov	35 - 40 %	57%	29%	33	9	2	1	-1	11	44	39%	7
4	44,000 ML/Day for 3 consecutive days between Jun & Nov	30 - 35 %	44%	22%	25	2	6	0	0	8	33	29%	6
5	63,250 ML/Day for 3 consecutive days between Jun & Nov	11 - 15 %	21%	11%	13	0	1	0	-2	-1	12	11%	10

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.14: Flow indicator achievement of mid-Murrumbidgee Wetlands flow indicators under without development, baseline and BP-3200-RC

			Without development	Baseline		BP-3200-RC							
Flow Indicator			Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Narrandera)		Target proportion of years with a successful event - high to low uncertainty				Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	26,850 ML/Day for a total duration of 45 days between Jul & Nov	20 - 25 %	28%	11%	13	0	0	5	-1	4	17	15%	12
2	26,850 ML/Day for 5 consecutive days between Jun & Nov	50 - 60 %	67%	46%	52	8	6	5	-1	18	70	61%	6
3	34,650 ML/Day for 5 consecutive days between Jun & Nov	35 - 40 %	57%	29%	33	8	3	5	0	16	49	43%	5
4	44,000 ML/Day for 3 consecutive days between Jun & Nov	30 - 35 %	44%	22%	25	3	7	0	-1	9	34	30%	12
5	63,250 ML/Day for 3 consecutive days between Jun & Nov	11 - 15 %	21%	11%	13	0	2	0	-2	0	13	11%	8

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.15: Flow indicator achievement of lower Murrumbidgee Floodplain flow indicators under without development, baseline and BP-2800-RC

			Without development	Baseline		BP-2800-RC							
Flow Indicator						Number of years with successful events							
	Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Maude Weir)	Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)	Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
1	Total volume of 175 GL (flow > 5000 ML/day) between Jul & Sep	70 - 75 %	94%	68%	77	3	0	24	0	27	104	91%	2
2	Total volume of 270 GL (flow > 5000 ML/day) between Jul & Sep	60 - 70 %	92%	57%	65	5	0	27	0	32	97	85%	8
3	Total volume of 400 GL (flow > 5000 ML/day) between Jul & Oct	55 - 60 %	92%	52%	59	10	0	25	0	35	94	82%	14
4	Total volume of 800 GL (flow > 5000 ML/day) between Jul & Oct	40 - 50 %	78%	39%	44	4	0	17	0	21	65	57%	13
5	Total volume of 1700 GL (flow > 5000 ML/day) between Jul & Nov	20 - 25 %	56%	18%	21	0	0	14	0	14	35	31%	9
6	Total volume of 2700 GL (flow > 5000 ML/day) between May & Feb	10 - 15 %	44%	9%	10	1	0	7	0	8	18	16%	7

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.16: Flow indicator achievement of lower Murrumbidgee Floodplain flow indicators under without development, baseline and BP-3200-RC

Flow Indicator			Without development	Baseline		BP-3200-RC							
	Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Maude Weir)	Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events					Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
						Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)			
1	Total volume of 175 GL (flow > 5000 ML/day) between Jul & Sep	70 - 75 %	94%	68%	77	3	0	26	0	29	106	93%	1
2	Total volume of 270 GL (flow > 5000 ML/day) between Jul & Sep	60 - 70 %	92%	57%	65	5	0	28	0	33	98	86%	7
3	Total volume of 400 GL (flow > 5000 ML/day) between Jul & Oct	55 - 60 %	92%	52%	59	10	0	26	0	36	95	83%	13
4	Total volume of 800 GL (flow > 5000 ML/day) between Jul & Oct	40 - 50 %	78%	39%	44	4	0	22	0	26	70	61%	14
5	Total volume of 1700 GL (flow > 5000 ML/day) between Jul & Nov	20 - 25 %	56%	18%	21	0	0	18	0	18	39	34%	10
6	Total volume of 2700 GL (flow > 5000 ML/day) between May & Feb	10 - 15 %	44%	9%	10	1	0	11	0	12	22	19%	8

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.17: Achievement of Balranald fresh flow indicators under without development, baseline and BP-2800-RC scenarios.

			Without development	Baseline		BP-2800-RC							
Flow Indicator						Number of years with successful events							
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Balranald Weir)		Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)	Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
1	1100 ML/Day for 25 consecutive days between Dec & May	58 - 77 %	96%	32%	37	0	0	39	-1	38	75	66%	9
2	4500 ML/Day for 20 consecutive days between Oct & Dec	54 - 72 %	90%	35%	40	0	0	41	0	41	81	71%	11
3	3100 ML/Day for 30 consecutive days between Oct & Mar	55 - 73 %	91%	29%	33	0	0	48	0	48	81	71%	6

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Table C.18: Achievement of Balranald fresh flow indicators under without development, baseline and BP-3200-RC scenarios.

Flow Indicator			Without development	Baseline		BP-3200-RC							
Flow Event - threshold, duration, season (as gauged on the Murrumbidgee River at Balranald Weir)		Target proportion of years with a successful event - high to low uncertainty	Proportion of years with a successful event	Proportion of years with a successful event	Number of years with a successful event	Number of years with successful events: Ordered and fully delivered (1)	Ordered and fully delivered within 10% (2)	Other successful events (3)	Baseline events lost (4)	Total additional to baseline (5) = (1+2+3+4)	Number of years with a successful event *	Proportion of years with a successful event *	Number of additional years with events partially delivered (6)
1	1100 ML/Day for 25 consecutive days between Dec & May	58 - 77 %	96%	32%	37	0	0	44	-1	43	80	70%	10
2	4500 ML/Day for 20 consecutive days between Oct & Dec	54 - 72 %	90%	35%	40	0	0	41	0	41	81	71%	11
3	3100 ML/Day for 30 consecutive days between Oct & Mar	55 - 73 %	91%	29%	33	0	0	52	0	52	85	75%	4

* Events which were included in the demand timeseries and were within 10% of the flow indicator parameters are considered as successful events (Appendix C).

Appendix D. Figures with daily CLLMM data for the period from 2000 to 2009

This appendix presents figures of daily data of Murray Mouth bed levels, flows over the Barrages, Lower Lakes' levels and salinity in the North and South Coorong Lagoons for the period from 1st July 2000 to 30th June 2009.

Data are presented in sets of three graphs, with varying combinations of scenarios:

- Top: without development[1], baseline, BP-2800 and BP-2800-RC
- Middle: without development[1], baseline, BP-3200 and BP-3200-RC
- Bottom: BP-2800, BP-2800-RC, BP-3200 and BP-3200-RC.

[1] Without development scenario not included for Lower Lakes Level

Figure D.1: Murray Mouth bed level from 1st July 2000 to 30th June 2009.

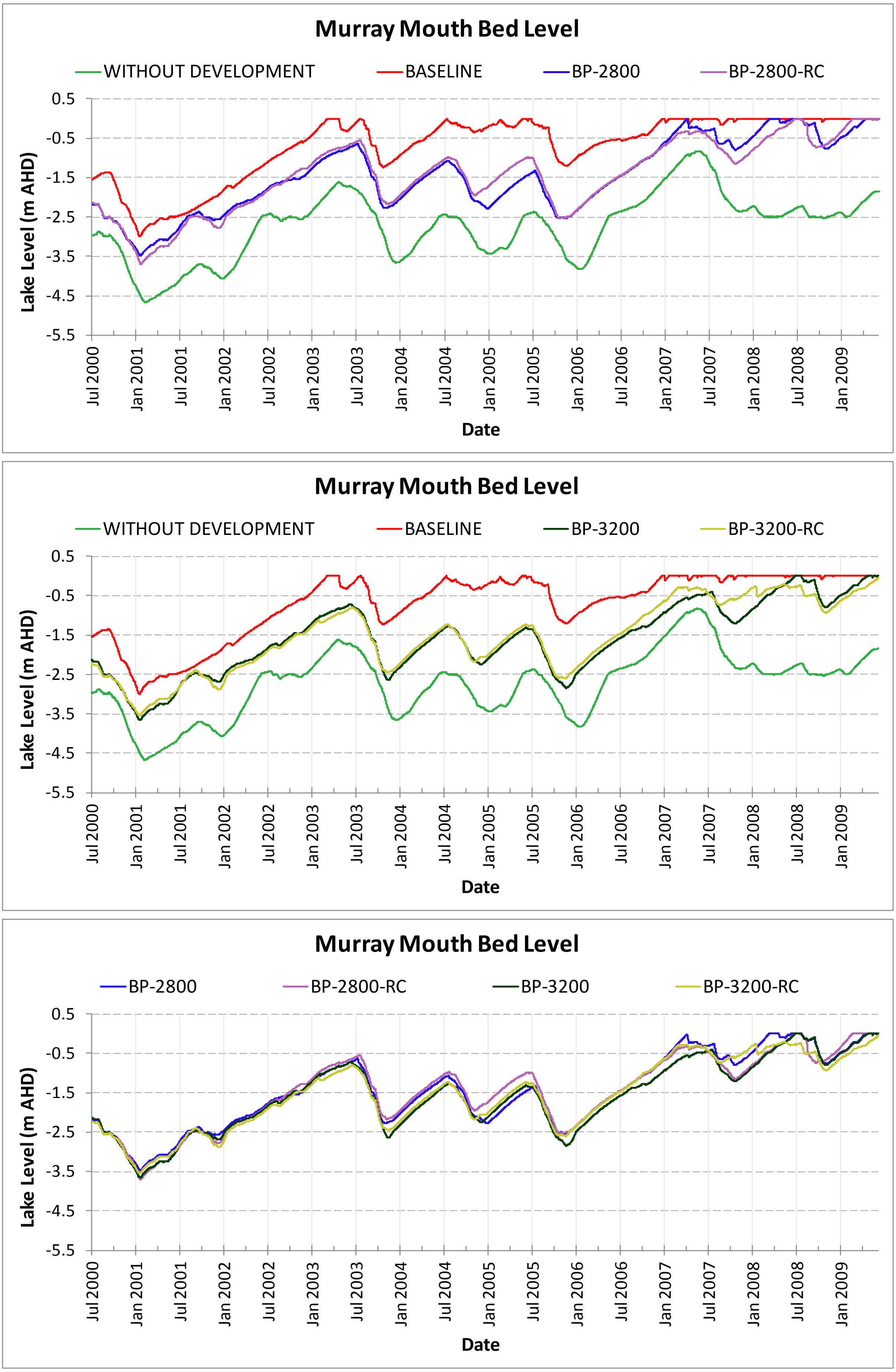
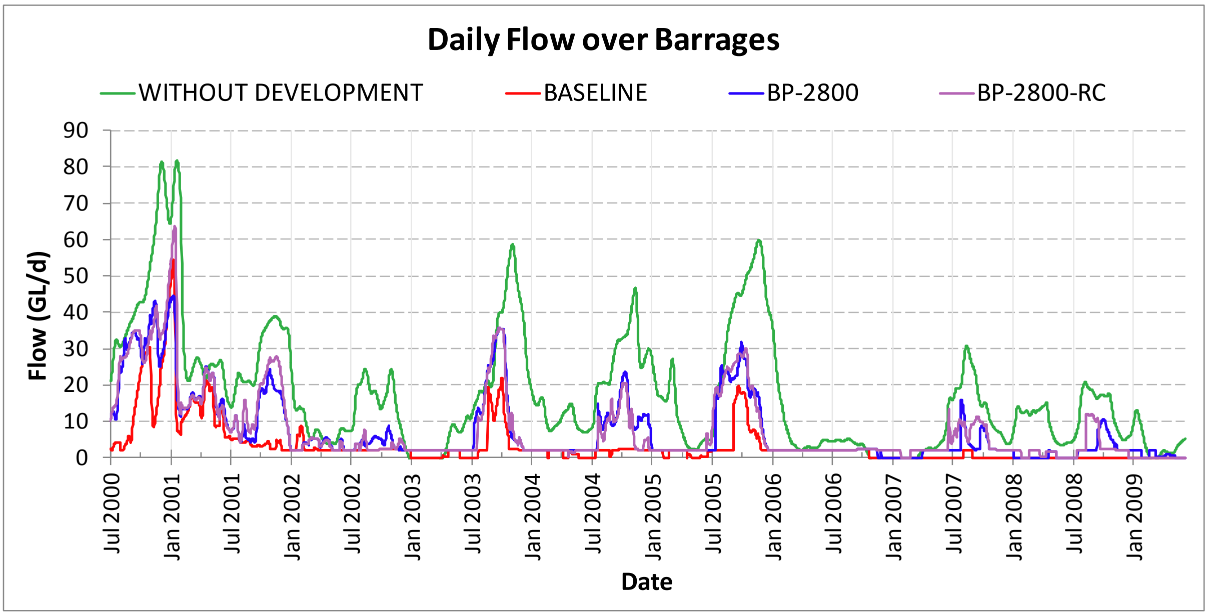
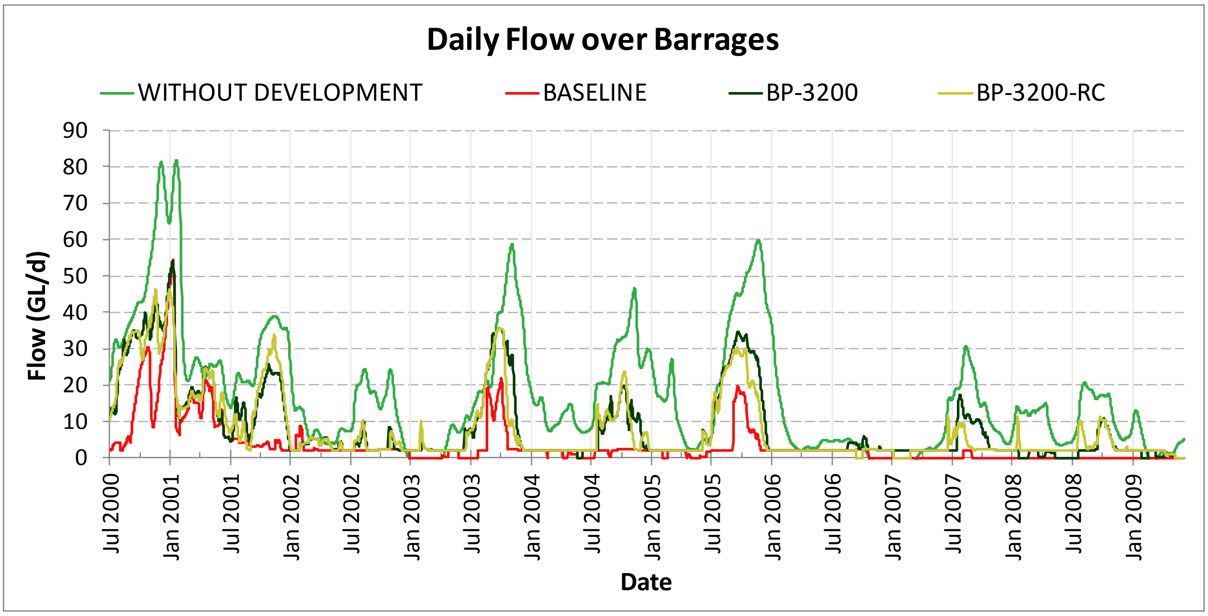


Figure D.2: Daily flows at the end of the Barrages from 1st July 2000 to 30th June 2009.





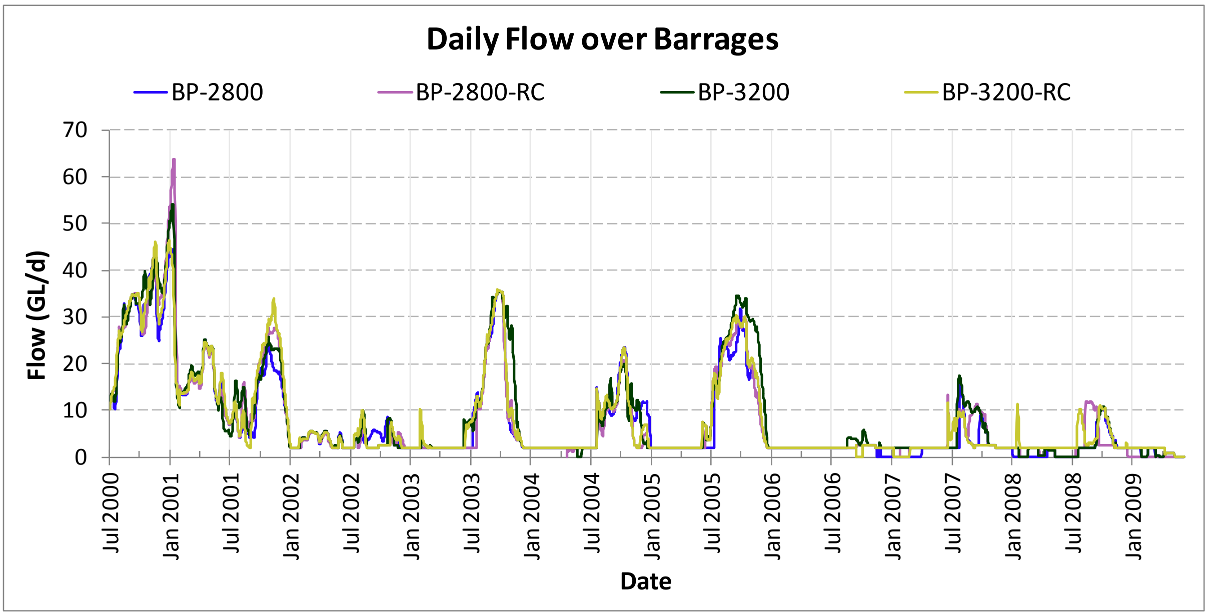
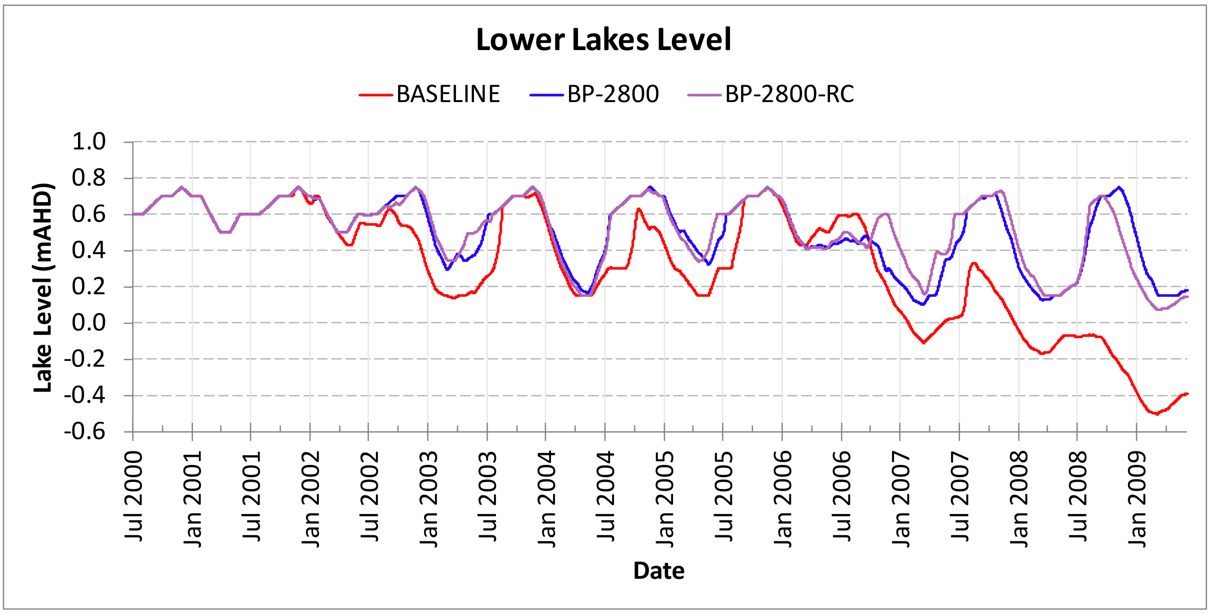
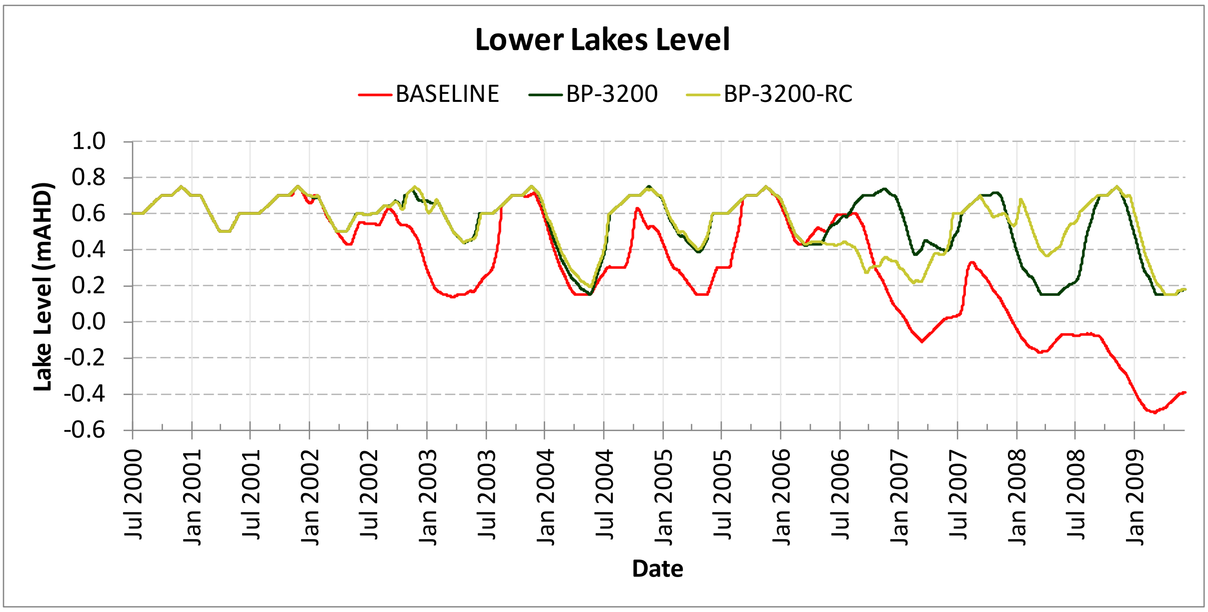


Figure D.3: Daily water level (m AHD) at Lower Lakes from 1st July 2000 to 30th June 2009.





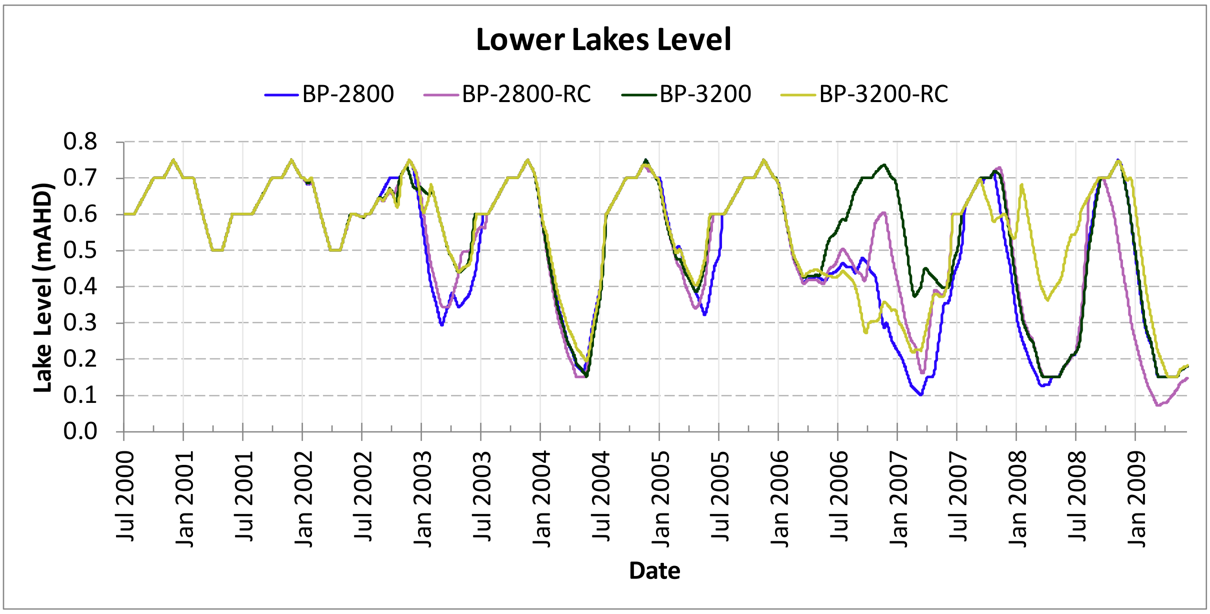
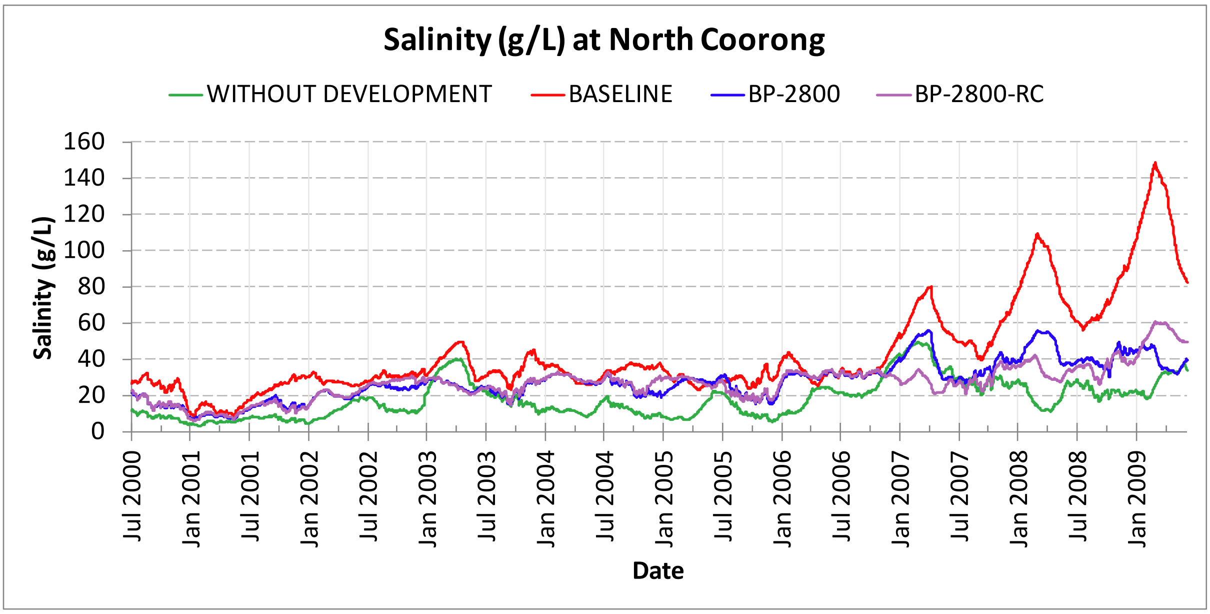
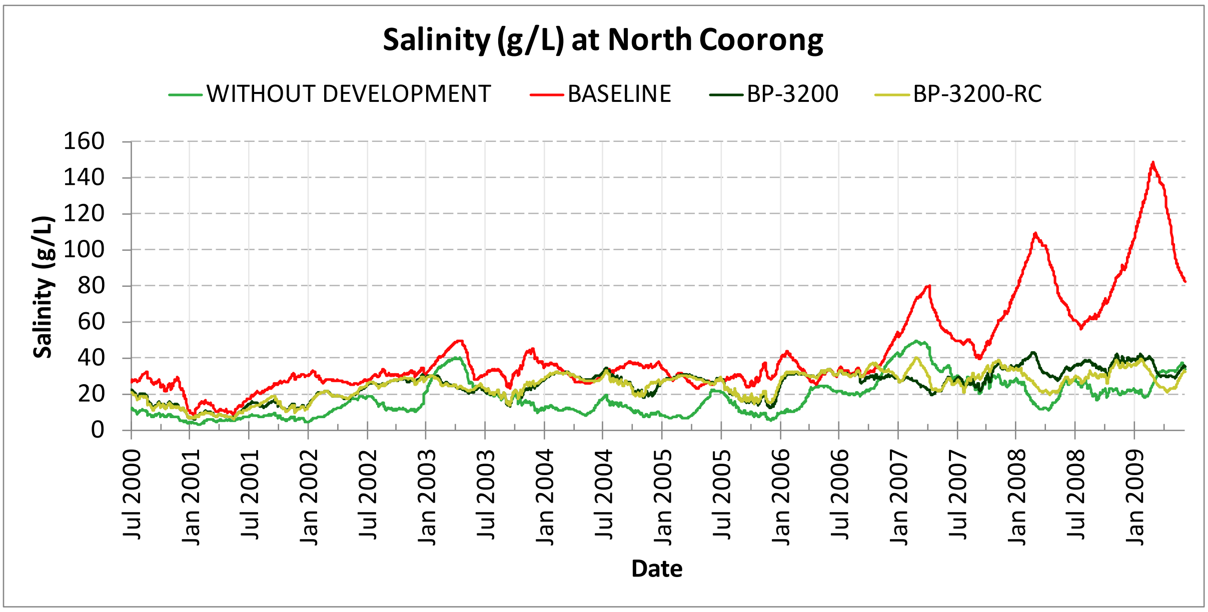


Figure D.4: Daily salinity (g/L) at the North Coorong Lagoon from 1st July 2000 to 30th June 2009.





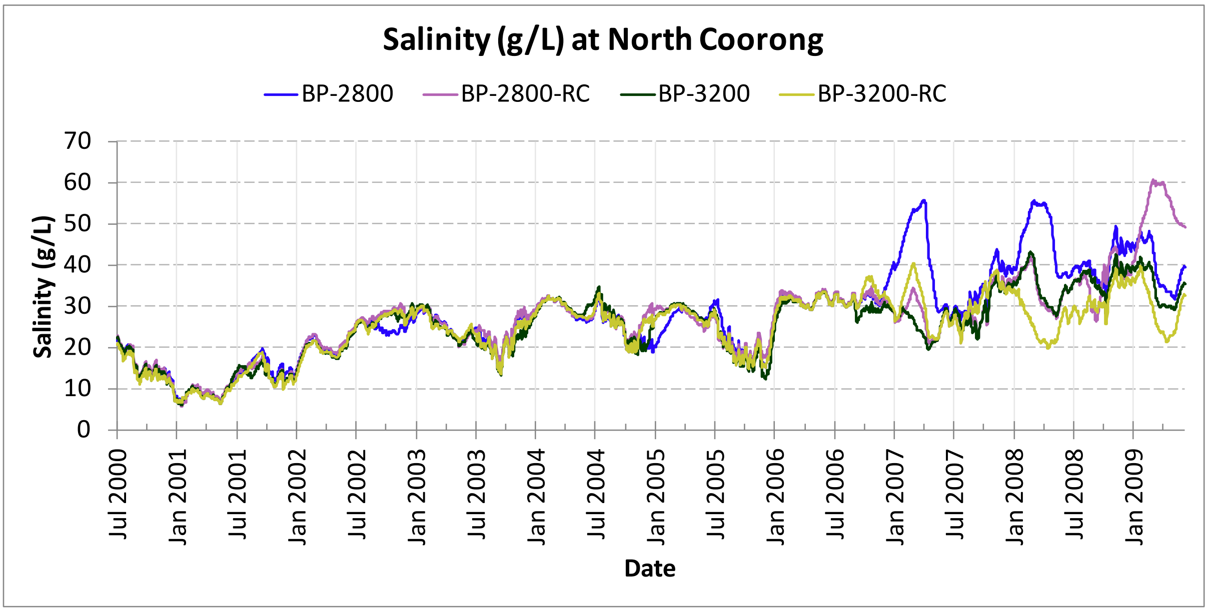


Figure D.5: Daily salinity (g/L) at the South Coorong Lagoon from 1st July 2000 to 30th June 2009.